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CITY OF ALAMEDA

SEISMIC SAFETY ELEMENT

A PART OF THE GENERAL PLAN
SAFETY ELEMENT

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SEISMIC SAFETY ELEMENT

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SAFETY ELEMENT

POLICY SECTION

Prepared by
ENVICOM CORPORATION

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Table of Contents

List of Figures

List of Tables

I. INTRODUCTION

A. LEGISLATIVE AUTHORITY

The California State Legislature, through requirements of the Seismic Safety and Safety Elements, has placed specific responsibilities on local government for identification and evaluation of natural hazards and formation of programs and regulations to reduce risk. Specific authority is derived from Government Code Sections 65302(f) and 65302.1 which require Seismic Safety and Public Safety Elements of all city and county general plans, as follows:

> "A Seismic Safety Element consisting of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to the effects of seismically induced waves such as tsunamis and seiches.
>
> "The Seismic Safety Element shall also include an appraisal of mudslides, landslides, and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards such as possible surface ruptures from faulting, ground shaking, ground failure, and seismically induced waves." (Section 65302(f)).
>
> "A Safety Element for the protection of the community from fires and geologic hazards including features necessary for such protection as evacuation routes, peak load water supply requirements, minimum road widths, clearances around structures, and geologic hazard mapping in areas of known geologic hazards." (Section 65302.1)

The effect of these sections is to require cities and counties to take seismic and other natural hazards into account in their planning programs. The principal catalyst for this requirement was the February 9, 1971 San Fernando earthquake in which 65 people were killed and property damage exceeded the billion dollar mark. Conclusions from the 1973 Urban

Geology Master Plan for California also give cause for considering geologic hazards in the planning process. Summary conclusions from this study estimate dollar losses due to geologic hazards in California between 1970 and 2000 will amount to more than $37 billion (Figure 1).

B. PURPOSE AND APPROACH

The basic objectives of the Seismic Safety and Safety Elements are to identify and evaluate natural hazards confronting cities and counties and to recommend policies that would reduce the adverse impact of those hazards if they are realized. Specifically, these elements evaluate both primary and secondary seismic hazards, flooding, fire, and aircraft crash hazards. The intent of the recommended policies is to provide an opportunity to reduce the loss of life, property damage, and social and economic dislocations in the event of a major earthquake, flood or fire.

The purpose of this document is to serve as an official guide to the City Council and the Mayor, the Planning Board and other governmental bodies, citizens, and private organizations concerned with natural hazards in the City of Alameda. The Seismic Safety and Safety Elements are intended to establish uniformity of policy and direction within the City government to minimize the risk from seismic events and other natural hazards. These Elements include goals, policies, safety criteria, and maps as a basis for decision-making in public and private development matters. Such information is to be used in conjunction with other established City policies

GEOLOGIC HAZARDS IN CALIFORNIA

TO THE YEAR 2000:

A $37 BILLION PROBLEM

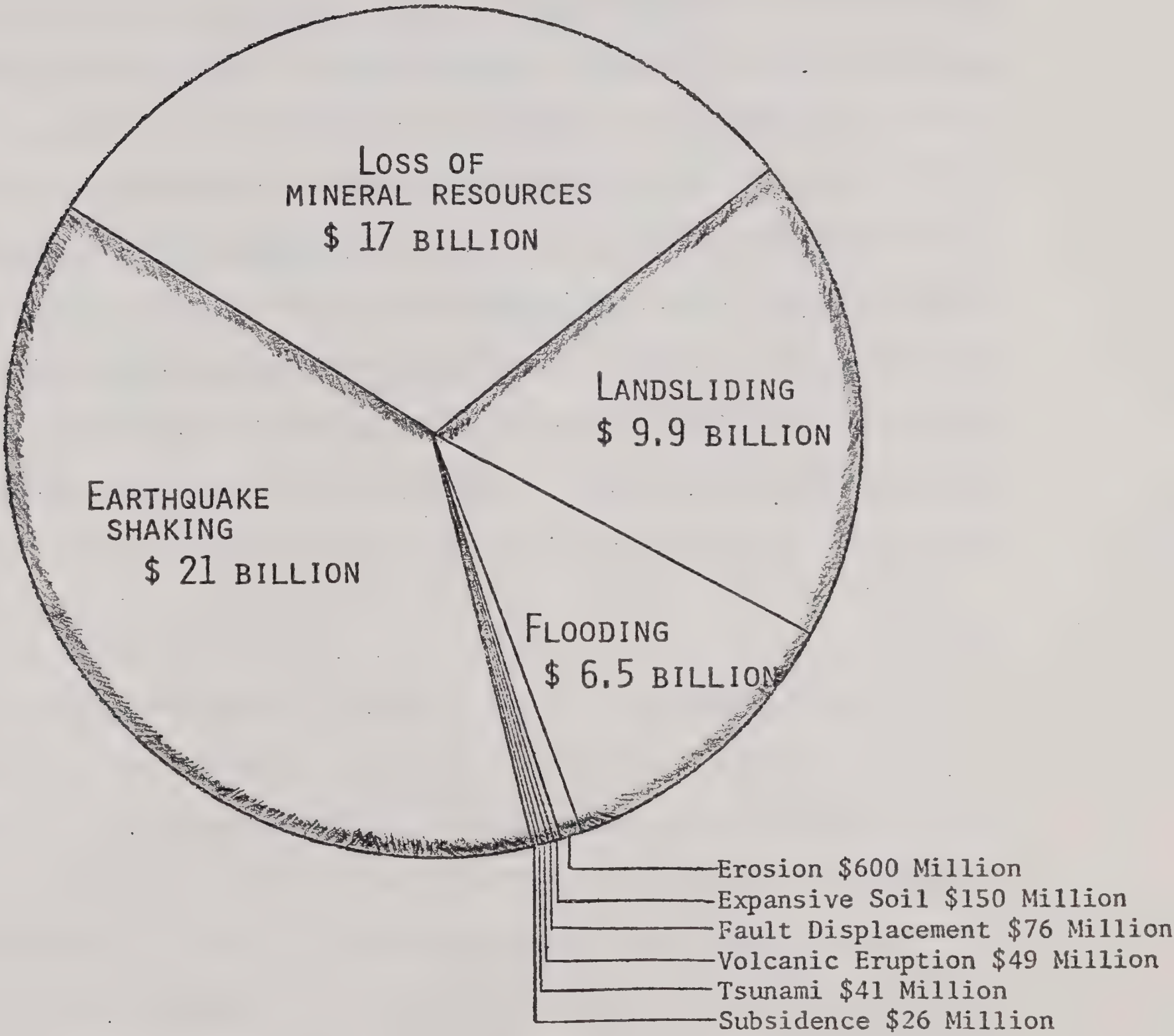


FIGURE 1.

Source: Urban Geology, Master Plan for California, Bulletin 198, 1973.

contained in the General Plan, and should play a major role in determining future land use.

The Seismic Safety and Safety Elements have been prepared as one report for the City of Alameda in two component sections. The first, the Policy Section, is concerned with the implications of the technical findings for the City, while the second, the Technical Section, addresses the nature and extent of seismic and fire hazards. It should be noted that the science of seismology is relatively young, and that much remains to be learned. The basic philosophy under which this document was prepared is that we should incorporate natural hazards analysis into the planning process based on what we know today, rather than waiting until we know all that we would like to know.

II. EXISTING CONDITIONS

A. TYPES OF HAZARDS

Two basic groups of natural hazards are considered in this document: seismic and fire hazards. A third category, flooding, is not considered a significant hazard in Alameda. There are several types of seismic hazards which can be grouped in a cause-and-effect classification that is the basis for the order of their consideration. Earthquakes originate as shock waves generated by movement along an active fault. The primary seismic hazards are ground shaking and the potential for ground rupture along the surface trace of the fault. Secondary seismic hazards result from the interaction of ground shaking with existing soil and bedrock conditions, and include liquefaction, settlement, landslides, tsunamis or "tidal waves", and seiches (oscillating waves in lakes and reservoirs).

The potentially damaging natural events (hazards) discussed above may interact with man-made structures. If a structure is unable to accommodate the natural event, failure will occur. The potential for such failure is termed a structural hazard, and includes not only structures themselves, but also the potential for damage or injury that could occur as the result of movement of loose or inadequately restrained objects within, on, or adjacent to a structure.

A more in-depth discussion of earthquake terminology and concepts is included in the Introduction of the Technical Report of the Seismic Safety Element, along with a Glossary

of Terms in back of this section (Appendix A).

Flooding hazards in the City of Alameda may be considered limited to that resulting from inadequate capacities of local storm drains following periods of heavy rainfall. Flooding of this type is local in nature, and usually results in inconveniences to local residents rather than significant, wide spread damage.

Fire hazards considered in this report are limited to urban fires. The built-up nature of the City precludes the possibility of damaging brush fires characteristic of more outlying locations.

B. TECHNICAL CONCLUSIONS

One of the principal objectives of the Seismic Safety and Safety Elements is to identify and evaluate the different types of seismic and fire hazards. These analyses are found in the Technical Section and form the basis for the recommended goals and policies of each Element. Major conclusions from the technical analysis are as follows:

Seismic Hazards

1. The City of Alameda is located in a part of California considered seismically active.
2. The states of activity of the major faults affecting the City have been evaluated using available published and unpublished data. Major conclusions are:

a. The San Andreas fault is active and is expected to be the source of a magnitude 8.0 - 8.5 earthquake in the forseeable future.

b. The Hayward fault zone is active and is expected to be the source of future significant earthquakes.

c. Earthquakes can and will occur on other faults in the region, but their effects on the study area will be less than those for the events on either the San Andreas or Hayward fault zones.

3. The earthquakes expected from the San Andreas and Hayward fault zones will result in ground shaking of approximately equal intensity in Alameda, depending on the characteristic of earthquake shaking applicable to a particular structure. Since the earthquake from the San Andreas fault zone has a greater risk of occurrence than that from the Hayward fault zone, the former is considered applicable to structures of non-critical use, and both events should be considered in the design of critical facilities.

4. Microzonation of the study area is based on the distance from the Hayward and San Andreas fault zones and the type of earth materials present. The ground shaking characteristics of each zone for each expected earthquake are presented as response spectra in the report, and the generalized characteristics of expected shaking to be applied to each of the zones in the City are summarized in Table 7. The areal distribution of the zones is shown on Plate I. The response spectra and Table 7 provide the necessary information to assist a structural engineer in modifying the existing building codes.

5. Liquefaction and settlement are considered significant hazards in all of the City. Soils engineering reports prepared for sites in the City should specifically address the problems of liquefaction and settlement, and evaluate them using the ground shaking parameters presented in this report.
6. Landsliding is not a significant hazard in the City because of the lack of significant topographic relief.
7. The hazard from tsunamis (i.e., "tidal waves") is present in the low-lying areas of the City. The area expected to be affected by a tsunami with a recurrence interval of approximately 200 years is shown on Plate I. The probable effect will be similar to rapidly fluctuating, exaggerated tides rather than large waves.

<u>Fire Hazards</u>

1. Fire hazards in the City of Alameda are of a wholly urban nature.
2. The major problem is fire in the large apartment complexes such as those in the South Shore Beach and Shore Point Road areas.
3. Problems of a somewhat less critical nature include fires at the Todd Shipyards and the Encinal terminals.
4. Rupture of local gas lines, downed electrical utility lines, or severed water mains, could compound fire hazards in the event of a major disaster such as an earthquake. The City does not have a secondary water supply for fire-fighting purposes.
5. The City of Alameda receives adequate fire protection through the City Fire Department.

Flooding Hazards

1. Flooding within the City is limited to storm drain inadequacies during periods of heavy runoff. Such flooding conditions which are local in nature and are variable in location do not pose a threat to general public safety.

C. HAZARD DELINEATION

The areal distribution of seismic hazards in the City of Alameda is shown on Plate I. Detailed discussions of the analyses of these hazards are contained in the Technical Section. A brief explanation is provided here as background for the recommended policies, and as an aid in interpreting Plate I.

1. Seismic Hazards

The primary seismic hazard of most concern to the City of Alameda is groundshaking, which is described on Plate I as a pattern of seismic zones. These zones were derived through an analysis of the variation in underlying geologic formations and distance from the Hayward and San Andreas fault zones. Variations within the study area were evaluated by means of three mathematical models representative of geologic conditions in the study area.

The seismic zones are expressive of the level of ground motion that can generally be anticipated from earthquakes on the principal fault systems affecting the City of Alameda. The characteristics of each seismic zone are represented by response spectra which translate ground motion into displacement (inches); velocity (inches per second); and acceleration

(inches per second per second, expressed as a percentage of the acceleration of gravity). These three factors, which are derived from mathematical analysis, essentially describe each seismic zone. These are the geophysical "tools" for use in designing structures. Specific values for these ground motion factors are contained in the response spectra graphs for each seismic zone (Technical Section pp. 65-70). Generalized characteristics for each seismic zone are contained in Table 7 of the Technical Section.

In summary, the following statements can be made regarding the seismic zones and secondary hazards within the study area:

a. The seismic zones have been derived from two basic sets of criteria: (a) distance from the source of an earthquake; and (b) geographical differentiation of soil and bedrock conditions. Distance zones are expressed in arabic numerals and the differentiations between soil and bedrock have been expressed in alphabetical form. The combination of a distance zone (1 or 2) <u>with</u> a soil/bedrock zone (S or M) constitutes a particular seismic zone.

b. The seismic zone analysis is based upon the Hayward and San Andreas fault systems as the principal sources of strong shaking.

c. Soil and bedrock conditions within the study area have been differentiated into two types as follows:

   Zone M Representative of areas underlain by Bay Mud.

   Zone S Representative of areas underlain by Merritt Sand.

In general forms, the levels of ground shaking from the expected earthquakes will be most severe in areas underlain by Bay Mud (Zone M). The strong ground shaking will probably be accentuated by lurching and surface deformation typically associated with these types of poorly consolidated, weak soils. Ground shaking in areas underlain by Merritt Sand (Zone S), while still expected to be severe, will be less intense than for areas underlain by Bay Mud.

d. The potential for liquefaction and/or settlement exists throughout the City. A tsunami hazard is present in low-lying areas along the Bay as delineated on Plate I.

2. <u>Fire Hazards</u>

The potential fire hazards discussed in the Technical Report are limited primarily to residential structures.

3. <u>Flood Hazards</u>

As indicated previously, flooding is not considered a significant public safety hazard, and as such, no attempt has been made to delineate flooding.

D. RISK

The Council on Intergovernmental Relations (CIR) defines "Risk" from natural and man-made hazards in three categories:

1. <u>Acceptable Risk</u>: The level of risk below which no specific action by government is deemed to be necessary.

2. <u>Unacceptable Risk</u>: The level of risk above which specific action by government is deemed to be necessary to protect life and property.

3. Avoidable Risk: A risk which need not be taken because individual or public goals can be achieved at the same, or less, total "cost" by other means without taking the risk.

Determining levels of appropriate or acceptable risk is a multi-disciplinary process which relies heavily on citizen input. There is no such thing as a perfectly hazard-free environment. Natural and man-made hazards of some kind are always present, especially in urban areas. However, effective loss-reduction measures can be used in mitigating the consequences of known hazards. The determination of acceptable risk involves making a judgment about risk, either explicit or implicit, which is a necessary step in planning for loss-reduction from natural hazards.

The central concept used in determining acceptable risk is the definition of natural events in terms of magnitude and frequency. The magnitude of an event refers to its size. Examples are the height of flood waters, the rating of an earthquake on the Richter scale, or the number of acres burned in a wildland fire. The frequency of an event refers to the number of times it occurs during a certain period of time. The relationship between magnitude and frequency is normally inverse. That is, the less often an event occurs, the greater its size and potential impact is likely to be. For example, earthquakes occur frequently in Alameda, but most often they are of low magnitude and do not seriously threaten the City. However, on relatively infrequent occasions an earthquake of large magnitude will occur and may result in severe damage. A way of summarizing this concept with respect to an earthquake is

that the longer it waits, the bigger it will be. With regard to risk, there is one important difference between flooding and earthquakes. Flooding is the result of a random combination of meteorological events, whereas current geologic theory indicates that the buildup of stress or strain along a particular fault system is more nearly constant. Therefore, the periodic release of stress or strain in the form of an earthquake is more apt to be regular.

The magnitude-frequency concept is involved in the decisions regarding acceptable risk in that the community must judge what magnitude event should be planned for. That judgment is based on the frequency or recurrence interval of the hazardous event. A description of the magnitude and other characteristics of the event are then developed through a technical analysis. This information allows planners and engineers to develop loss-reduction measures, and to design structures to provide protection up to the level of acceptable risk. In this sense, the magnitude earthquake or flood used in defining acceptable risk may be thought of as a "design earthquake" or "design flood."

The determination of acceptable risk from hazardous events also involves differentiating among man-made structures according to their potential effect on the loss of life and their importance in terms of continued community functioning. In the hours immediately following the 1971 San Fernando earthquake in Southern California, emergency services were impaired by damage to police and fire stations, communication

networks and utility lines. Several hospitals were seriously damaged and unable to continue functioning. These facilities and others are vital to the community's ability to respond to a major disaster and to minimize loss of life and property. The experience in San Fernando emphasized the need to provide these "critical facilities" a higher level of protection from earthquakes than limited or normal occupancy structures or other non-critical structures. As a minimum, all structures which could have an effect on the loss of life should be designed to remain standing in the event of a major earthquake even if rendered useless. Critical facilities, on the other hand, should not only remain standing, but should be able to operate at an acceptable level of efficiency in the event of a disaster. The taxonomy of Critical Facilities presented in Table 1 is intended for use as a guide in evaluating the importance of each facility to overall public safety relative to a hazardous event such as a severe earthquake.

Based on the discussion above and on input from the Planning Board Workshop, held on September 15, 1975, the following seismic events are recommended as the basis for establishing earthquake design standards:

Use	Approximate Recurrence Interval (Years)	Magnitude (By Fault)	
		Hayward	San Andreas
Non-Critical Facilities (residences, normally occupied factories, etc.)	100	--	8.5
Critical Facilities (hospitals, fire and police stations, schools, major utilities, etc.)	70-100	7.0	8.5

The risk of an earthquake on the San Andreas fault is a special case because 70 years (1906 to 1976) of the recurrence interval have elapsed. As a result, all structures should be considered in terms of an earthquake of magnitude 8.5 on the San Andreas fault.

TABLE 1

TAXONOMY OF CRITICAL FACILITIES

Land Use/Facility	Safety Characteristic: Potential Effect on Loss of Life	Safety Characteristic: Emergency Response	Safety Characteristic: Vital Function	Classification: Critical	Classification: Normal
Developed Land					
RESIDENTIAL					
- Single Family					X
- Multi-family and Mobile homes					X
- Apartments					X
COMMERCIAL					
- Neighborhood Centers (e.g., grocery, barber, drug store)					X
- Community Centers (e.g., private offices, banks, restaurants, comparison shopping)					X
- Highway Centers (e.g., motels, fast food, restaurants)					X
- Heavy Commercial/ Light Industry (e.g., contractors yards, distribution warehouses, manufacturing and assembly plants)					X
- Heavy Industry					X
PUBLIC AND SEMI-PUBLIC USES					
- Hospitals		X	X	X	
- Schools/Colleges	X			X	
- Parks and Recreation Areas					X
- Government Facilities (e.g., civil defense quarters, fire and police stations, government offices)		X	X	X	
- Utilities (e.g., power plants (nuclear fossil fuel) gas and electric lines and stations, large dams, radio/ TV/microwave centers and lines, aqueducts, pipelines, sewage treatment facilities, gas stations, waterworks)		X	X	X	
- Roads and Highways		X	X	X	
- Railroads			X	X	
- Airports			X	X	
- Assembly Halls (e.g., theaters, auditoriums)	X			X	
- Refuse Disposal Sites					X
- Cemeteries					X
Undeveloped Land					
- Agriculture					X

III. HAZARD REDUCTION

A. BUILDINGS

1. Building Occupancy

The type of occupancy is important in determining the level of acceptable risk, i.e., the acceptable risk of failure or loss of function for a building. Building occupancy may be divided into three separate components: number of occupants, function of the occupancy, and economic value.

- The number of occupants is important in determining an acceptable risk level. Building occupied by two persons, 200 persons, or 2,000 persons would generally not be classified within the same risk level. Where more lives are involved, more protection should be required.
- The function of the occupancy, particularly when the function is vital to the safety and normal functioning of the community, has to be considered in determination of the acceptable risk level of a building. Collapse of a warehouse may be acceptable to a community, but the police or fire department should continue to function with the minimum of constraints after an earthquake.
- The economic value of a structure is important to the community as well as its owner. Its loss will have an economic and social impact in the community in proportion with its economic value.

2. Magnitude of Earthquake Forces

The impact of an earthquake force on a building is related

to magnitude of the earthquake, geological characteristics of the region, distance to the earthquake epicenter, type of rock between the site and the epicenter and the type of soil below the site. These factors in relation to Alameda are discussed in the Technical Report. We can do very little to change these factors except to classify them and assign relative values, and then to develop appropriate building design critera.

3. Type of Structure

Behavior of a structure during an earthquake is closely related to the construction type of the building. Since different construction materials have different ductility and strength, they react to the earthquake forces differently. The shape and geometry of a building also may have considerable effect on the potential for damage to a particular building during an earthquake. For example, a general discussion of typical building behavior for wood frame, unreinforced and reinforced masonry is as follows:

- Wood frame buildings behave in a ductile manner during earthquakes. As a general statement, wood frame buildings are the most earthquake resistant type of common construction. However, they are fire prone, and in some large earthquakes, the wood-frame buildings have survived the earthquake but have been destroyed by the post-earthquake fires.

- Unreinforced masonry structures have little resistance to earthquake shaking. They are brittle and in small earthquakes, they crack; in stronger quakes, they generally collapse.
- Reinforced masonry buildings, when properly designed and constructed are more earthquake resistant than unreinforced structures. However, they are also relatively brittle and in strong quakes they may crack or collapse.
- Behavior of reinforced concrete buildings during earthquakes is largely dependent on the design of the structure.
- Structural steel frame buildings are the most ductile structures of all the three types mentioned immediately above. During an earthquake, they may deform, but they can generally withstand more intense shaking without collapse.

4. Unreinforced Masonry Buildings

Unreinforced masonry buildings are structures which have load carrying walls built without reinforcing steel. The Riley Act, adopted in 1933 by the California State Legislature has effectively prohibited the construction of this type of building.

The earthquake resistance of unreinforced masonry buildings is about nil. Experience in Southern California, as well as with earthquakes elsewhere in the world, has shown that unreinforced masonry buildings collapse suddenly during earthquakes.

In California earthquakes, many casualties have resulted from the collapse of unreinforced masonry buildings. In the February, 1971 San Fernando earthquake, when 68 people died, forty-nine or 85% lost their lives in unreinforced masonry buildings that collapsed.

A number of government agencies and a number of professional groups have investigated the problem of unreinforced masonry structures. Technical findings of all of these investigations can be summarized simply as: "Unreinforced masonry structures are unsafe, and they present an unacceptable level of risk to the community. However, economic and social aspects of the problems are complex."

In the past, Building Department policy with respect to these structures in Alameda has been to allow existing occupancies to continue undisturbed. Presently, in the City, there is no program for repair or condemnation of unreinforced masonry structures; nor is there a program designed to provide warning of the hazard to the people entering, residing or leasing these unsafe structures.

Structural inspection of both critical and non-critical buildings is important to the implementation of this General Plan Element. Table 2 summarizes recommended structural inspection priorities.

TABLE 2

STRUCTURAL INSPECTION SEQUENCE MATRIX

Facility Type	Pre-1933 Riley Act Buildings	after 1933, before 1961 UBC	After 1961 UBC
Critical	1	2	4
Non-Critical	3	5	6

Those buildings with the highest priority should be considered for inspection before those of intermediate or low ranking.

B. ECONOMIC & SOCIAL & POLITICAL IMPLICATIONS

Any proposal to require the upgrading, modification, or elimination of a structure affects the owners and occupants of the structures in a very direct economic way. Usually, the entire cost of building improvement must be borne by the owner. The cost of improvments must in turn be passed on to the users of such facilities.

Old buildings, in particular, may house marginal businesses where a substantial rent increase may mean the operation is no longer profitable. In the case of residential buildings, social problems often result when low and/or fixed income

persons are displaced, either as a result of the building being torn down or as a result of increased rents necessitated by building rehabilitation. There is no easy solution to the problem of the social and economic impacts which result from a city's determination that, in the interest of public safety, all buildings shall conform to minimum seismic standards. The problem is particularly acute if the building in question is of unreinforced masonry construction, because the cost of the structural improvements required to make such buildings conform to current seismic standards sometimes necessitates an investment that is greater than the value of the building.

For the community of Alameda, the problem of unreinforced masonry construction has two facets. First, the buildings represent a real hazard to the general public. A majority of the buildings are located in the Park Street area of the City, and house retail stores with intensive public use. A major quake in the daytime or early evening hours would undoubtedly result in a substantial loss of life. Second, the retail activities that operate in such buildings contribute directly to the City's revenues through property taxes and the generation of sales taxes. Destruction of these buildings by a major quake would cause a substantial loss of tax revenue to the City. On the other hand, even the gradual elimination of these buildings through a City code enforcement program could have a serious economic

impact on revenues, because retail shopping areas require a "mix" of uses to function effectively.

Gradual replacement or rehabilitation of unreinforced masonry buildings in the Park Street area may be possible, but the program must be devised very carefully to minimize the economic impact on City revenues.

Finally, it should be noted that programs which require major building upgrading or reconstruction may be very unpopular even in the face of overwhelming evidence that the buildings are unsafe. However, a program which offers some options to the property owner may be more palatable, and will enable the City to assure that the public is reasonably protected in the event of a moderate or greater magnitude earthquake.

C. UTILITIES & PUBLIC FACILITIES

Damage to utility systems as the result of an earthquake is of two primary types. First, buildings and structures housing components of the system, and equipment contained within the building essential to the functioning of the system, may be damaged as a result of earth shaking. Generally, the problem of damage to utility system buildings, electrical substations, etc., is of greater concern, because a loss of service to a very widespread area may occur. Repair may involve considerable time and effort.

Public facilities, particularly those important in the aftermath of an earthquake, should be designed to withstand the anticipated ground shaking.

D. GOAL RECOMMENDATIONS

To plan effectively for reducing hazards to acceptable levels of risk, it is necessary that goals be set and adhered to. Goals address general policy directions which form the basis for planning decisions and actions. The recommended goals for hazard reduction in the City of Alameda are:

1. To minimize injury and the loss of life from major seismic events.

2. To minimize damage to public and private property.

3. To minimize social and economic dislocations.

4. To aid in the restoration of public services to citizens to provide for an early return to a normal level of activity.

The technical and planning recommendations of the next two sections complement the planning goals and define specific directions for the City to take in reducing natural hazards.

E. POLICY RECOMMENDATIONS

The following recommended policies complement the planning goals and define specific directions for the City to take in

reducing natural hazards.

1.0 Adopt new ordinances and amend existing ordinances which require the incorporation of seismic safety and safety considerations in developments under the City's jurisdiction.

2.0 Provide for the identification and evaluation of existing structural hazards.

3.0 Risks associated with hazardous structures should be reduced to acceptable levels through orderly hazard reduction programs.

4.0 Regulate land use in areas of significant natural hazard.

5.0 Provide for the education of the community regarding the nature and extent of natural hazards in the study area.

6.0 Provide for the maintenance and upgrading of disaster response plans.

7.0 Provide for review and updating of the Seismic Safety and Safety Elements.

F. IMPLEMENTATION RECOMMENDATIONS

The implementation recommendations in this section are intended to provide the City with a series of specific planning actions

to achieve the goals of these Elements and carry out the policies recommended above. While it would be advisable to fully implement each of the recommended actions, it is recognized that unlimited resources to that end are not available. These recommended actions should be thought of, then, as options to be implemented as resources provide. To aid in determining priorities for the allocation of resources in the community, the recommended policies and actions are listed below in their general order of importance to achieving the goals of these Elements.

1.0 Adopt new ordinances and amend existing ordinances which require the incorporation of seismic safety and safety consideration in developments under the City's jurisdiction

1.1 Adopt the most recent (1976) Uniform Building Code.

1.2 The geological data provided in the Seismic Safety Element should be made available to developers in the City to utilize in constructing new buildings for maximum earthquake safety.

1.3 Consideration should be given to separate code revisions for existing buildings versus new buildings, with the provisions for existing structures taking into account the overall risk factor.

2.0 Provide for the identification and evaluation of existing structural hazards

2.1 It is recommended that structures within the City be inspected for conformance with the amended Uniform Building Code earthquake regulations. Inspections should be conducted according to the following priorities:

(b) other critical facilities (e.g., schools, utility lines, government buildings)

(c) normal or limited occupancy non-critical facilities (offices, low density residential buildings)

Within each priority group, it is recommended that facilities built before 1933 be inspected first, then those built between 1933 and 1961, and lastly, those constructed after 1961. The significance of the year 1933 is that the Field and Riley Acts became law in California that year and required reinforcement in schools and certain other structures (Appendix C). Structures built before 1933, especially larger commercial structures, are more likely to be unreinforced masonry block buildings which are most susceptible to collapse in earthquakes. In 1948, earthquake regulations were adopted as a legally binding section of the UBC for the first time. Previously, earthquake standards were set forth in the Appendix of the UBC and were not a mandated part of the Code. It is more likely, then, that a building constructed before 1948 would be less able to withstand the shock of an earthquake than one built after 1948. It is also recommended that public structures be inspected before private structures.

Table 3 (abridged from Pacific Fire Rating Bureau, presently named Insurance Services Office), may also be used as a general indicator in older construction for use in establishing a priority ranking system for evaluating structures. Buildings with a high susceptibility to damage (rating five or over) should be selected for structural inspection before those with low ratings. A high priority should be placed on establishing a definition of facilities that handle explosive, flammable, or toxic materials and on an evaluation of their seismic vulnerability.

An alternative method for evaluating and abating the structural hazards of existing buildings is the program developed by Professor Bresler of the University of California at Berkeley for the Applied Technology Council.

2.2 Caltrans and Alameda County, which are the agencies responsible for the main tubes and bridges

TABLE 3.

HAZARD COMPARISON OF NON-EARTHQUAKE-RESISTIVE BUILDINGS

Simplified Description of Structural Type	Relative Damagability (in order of increasing susceptibility to damage)
Small wood-frame structures, i.e. dwellings not over 3,000 sq. ft. and not over 3 stories	1
Single or multistory steel-frame buildings with concrete exterior walls, concrete floors, and concrete roof. Moderate wall openings	1.5
Single or multistory reinforced-concrete buildings with concrete exterior walls, concrete walls, and concrete roof. Moderate wall openings	2
Large area wood-frame buildings and other wood frame buildings	3 to 4
Single or multistory steel-frame buildings with unreinforced masonry exterior wall panels; concrete floors and concrete roof	4
Single or multistory reinforced-concrete frame buildings with unreinforced masonry exterior wall panels, concrete floors and concrete roof	5
Reinforced concrete bearing walls with supported floors and roof of any material (usually wood)	5
Buildings with unreinforced brick masonry having sand-line mortar; and with supported floors and roof of any material (usually wood)	7 up
Bearing walls of unreinforced adobe, unreinforced hollow concrete block, or unreinforced hollow clay tile	Collapse hazard in moderate shocks
This table is intended for buildings not containing earthquake bracing, and in general, is applicable to most older construction. Unfavorable foundation conditions and/or dangerous roof tanks can increase the earthquake hazard greatly.	

into and within Alameda, should review these facilities to determine the potential impact of expected earthquakes, and should report their findings to the City.

2.3 The Bureau of Electricity should review its distribution and substation facilities to determine the potential impact of expected earthquakes, and should forward comments to the City. Pacific Gas and Electric should also review its gas lines for potential fire hazards.

2.4 The Alameda Fire Department should continue and/or expand its fire hazard inspection program for structures within its jurisdiction.

3.0 Risks associated with hazardous structures should be reduced to acceptable levels through orderly hazard reduction programs

3.1 Structures identified as hazardous in terms of fire and earthquake damage should be brought into conformance with acceptable levels of risk by programs including, but not limited to, structural rehabilitation, occupancy reduction, and demolition and reconstruction.

3.2 The City should advocate the expansion of State and Federal relocation assistance funds and programs to aid persons and businesses displaced from hazardous buildings.

4.0 Provide for more detailed scientific analyses of natural hazards in the study area

4.1 Require site-by-site soils and geologic engineering studies for potential liquefaction and settlement and evaluate these potential hazards using the ground shaking parameters presented in the Technical Report.

4.2 Institute a building strong-motion instrumentation program for buildings over four (4) stories in height, if such buildings are anticipated.

4.3 As a part of the site analysis for new developments along the Estuary, the potential for slope failure, and the possibility of mitigating measures, should be investigated.

5.0 <u>Regulate land use and building in areas of significant natural hazard</u>

5.1 No new structure should be permitted unless it conforms to the recommended revised Uniform Building Code Earthquake Regulations.

5.2 No critical facilities should be permitted without requiring a detailed site investigation which addresses the potentials for liquefaction and settlement.

5.3 No critical facilities should be located in low lying coastal and inland portions of the study area subject to potential tsunami hazards.

6.0 <u>Provide for the education of the community regarding the nature and extent of natural hazards in the study area</u>

6.1 Develop an information release program to familiarize the citizens of Alameda with the Seismic Safety and Safety Elements. Special attention should be afforded to those groups particularly susceptible to seismic and fire hazards, including but not limited to, school districts, agencies involved with the aged, and agencies involved with handicapped persons. These agencies should be encouraged to develop educational programs of their own relative to hazard awareness. The conclusions and recommendations of these elements should also be provided to land developers and those involved in the real estate profession. Appendix B provides a list of earthquake safety procedures.

6.2 Initiate education programs in lower grades using displays and demonstrations that would expose younger children to the nature and strength of fire. Such programs would tend to replace their natural curiosity with a sense of respect.

7.0 <u>Provide for the maintenance and upgrading of disaster response plans</u>

7.1 Maintain a disaster response program for the City of Alameda. Objectives of the program should be prepared in accordance with State and Federal regulations.

(a) To save lives and protect property.
(b) To provide a basis for direction and control of emergency operations.
(c) To provide for the continuity of government.
(d) To repair and restore essential systems and services (e.g., emergency water supplies).
(e) To provide for the protection, use and distribution of remaining resources.
(f) To coordinate operations with the civil defense emergency operations or other jurisdictions.
(g) To provide for a maximum degree of self-sufficiency by the City in the event of a major disaster.

Since a large earthquake will severely affect many cities and hundreds of thousand of people, the efforts of the Federal and State emergency services will be severely over-extended. It is advisable that the City of Alameda be prepared to serve itself and maintain continued functioning of necessary services rather than expect adequate aid from outside organizations although it is recognized that a major federal installation in Alameda (NAS Alameda) could provide substantial assistance to the City in the case of an earthquake emergency.

7.2 Conduct periodic earthquake, tsunami and fire emergency drills. These drills should be coordinated on a regional basis in cooperation with all involved jurisdictions.

7.3 The City should examine its system for provision of water supply for fire-fighting purposes during and after an earthquake. If the system is susceptible to seismic damage, emergency back-up systems should be investigated.

8.0 <u>Provide for review and updating of the Seismic Safety and Safety Elements</u>

8.1 The Seismic Safety and Safety Elements should be reviewed by the City Planning Department annually and should be comprehensively revised every five years or whenever substantially new scientific evidence becomes available.

IV. RELATIONSHIPS TO OTHER GENERAL PLAN ELEMENTS

The Seismic Safety and Safety Elements are the major natural hazards analyses in the General Plan and, as such, have important policy implications for other elements in the Plan. In particular, the Seismic Safety and Safety Elements provide significant information for the Land Use, Housing and Circulation Elements. It is recommended that these Elements be prepared or revised to give specific recognition to the policies adopted in the Seismic Safety and Safety Element.

The Land Use Element will be influenced most directly by the recommendations of Policy 5.0 to regulate land use in areas of significant natural hazards. The Land Use Element may also recommend land use controls for those areas in which "stacking" or combinations of individual hazard zones result in a high level of overall hazard. Figure 2 shows the effects of "stacking" on various land uses.

The policies of these Elements provide input to the Housing Element primarily by recommending design and construction modifications. The following recommendations pertain directly to the Housing Element:

1. All new construction should conform to the revised Uniform Building Code Earthquake Regulations.

2. Existing high occupancy residential structures found to be seismically vulnerable should be strengthened or replaced or their occupancy level should be reduced.

The Circulation Element should recognize that the transportation network connecting to Alameda could be seriously affected in the

	BUILDING TYPE/LAND USE	SEISMIC, LIQUEFACTION AND TSUNAMI HAZARD ZONES (SHOWN ON PLATE I)					
		1/ 1S	2S	IM	2M	2/ LIQU	3/ TSUN
CRITICAL FACILITIES	Power Plants, Civil Defense Headquarters, Hospitals, Fire Stations, Ambulance Services, Life Line Systems for Gas, Electric, Water, Telephone, Emergency Broadcast Systems.	●	●	●	●	⊘	●
CRITICAL FACILITIES	Schools, Theaters, Auditoriums, Police Stations, Utility Substations, Sewage Treatement Plants, Waterworks, Local Gas and Electric Lines, Major Highways, Bridges, Tunnels, Aqueducts, Pipe Lines, Public Service Facilities, Public Assembly-Capacity of 100 or more.	⊘	⊘	●	●	⊘	●
NON-CRITICAL FACILITIES	Heavy Industrial, Office Buildings, Commercial Centers, Hotels and Motels, Banks and Financial Establishments, Residential Housing, Service Stations, Health Care Clinics, Light Industrial, Warehousing and Storage, Parks, Refuse Disposal Sites	⊘	⊘	⊘	⊘	⊘	⊘

FIGURE 2

Explanation

○ Generally suitable for development

⊘ Suitable for development with study/hazard mitigation

● Generally unsuitable for development without appropriate mitigation measures

1/ Ground shaking zones

2/ Liquefaction potential zone (all of City)

3/ Tsunami Hazard Zone

Notes: This figure is for General Planning purposes only. Suitability for specific uses and sites must be confirmed by further investigation. An area evaluated as generally unsuitable for a particular use does not necessarily preclude the use, if no other suitable alternative sites are available and all potential hazards can be mitigated.

event of a major earthquake. An earthquake will impact primarily water crossings. Therefore the greatest potential danger in Alameda is to the bridges and tunnels which provide the City's connecting links with the rest of the region. Damage of the facilities could affect receipt of critical goods and services. New construction of bridges, overpasses, and other grade crossings should also utilize seismic response design criteria.

APPENDIX A

Glossary of Terms

Active Fault - One that has moved in recent geologic time and which is likely to move again in the relatively near future. Definitions for planning purposes extend on the order of 10,000 years or more back and 100 years or more forward.

Alluvial - Pertaining to or composed of alluvium, or deposited by a stream or running water. (AGI, 1972)

Alluvium - A general term for clay, silt, sand, gravel or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope. (AGI, 1972)

Amplification - Elaboration; augmentation; addition (Webster). As used herein, near-surface amplification is the augmentation of wave amplitude resulting from the change in physical properties in near-surface layers (see Introduction).

Amplitude - The extent of the swing of a vibrating body on each side of the mean position. (Webster)

Block Glide - A translational landslide in which the slide mass remains essentially intact, moving outward and downward as a unit, most often along a pre-existing plane of weakness such as bedding, foliation, joints, faults, etc. (AGI, 1972)

Cohesion - Shear strength in a sediment not related to interparticle friction. (AGI, 1972)

Colluvium - (a) A general term applied to any loose, heterogenous, and incoherent mass of soil, material or rock fragments deposited chiefly by mass-wasting, usually at the base of a steep slope or cliff. (b) Alluvium deposited by unconcentrated surface runoff or sheet erosion, usually at the base of a slope. (AGI, 1972)

Compaction - Reduction in bulk volume or thickness of, or the pore space within, a body of fine-grained sediments in response to the increasing weight of overlying material that is continually being deposited, or to the pressure resulting from earth movements within the crust. It is expressed as a decrease in porosity brought about by a tighter packing of the sediment particles. (AGI, 1972)

Consolidated Material - Soil or rocks that have become firm as a result of compaction.

Critical Damping - Damping to the point at which the displaced mass just returns to its original position without oscillation. (AGI, 1972).

Damping - The resistance to vibration that causes a decay of motion with time or distance, e.g. the diminishing amplitude of an oscillation. (AGI, 1972)

Differential Settlement - Nonuniform settlement; the uneven lowering of different parts of an engineering structure, often resulting in damage to the structure. (AGI, 1972)

Displacement (Geological) - The relative movement of the two sides of a fault, measured in any chosen direction; also, the specific amount of such movement. Displacement in an apparently lateral direction includes strike-slip and strike separation; displacement in an apparently vertical direction includes dip-slip and dip separation. (AGI, 1972)

Displacement (Engineering) - The geometrical relation between the position of a moving object at any time and its original position. (Webster)

Epicenter - That point on the Earth's surface which is directly above the focus of an earthquake. (AGI, 1972)

Fault - A surface or zone of rock fracture along which there has been displacement, from a few centimeters to a few kilometers in scale. (AGI, 1972)

Fault Surface - In a fault, the surface along which displacement has occurred. (AGI, 1972)

Fault System - Two or more interconnecting fault sets. (AGI, 1972)

Fault Zone - A fault zone is expressed as a zone of numerous small fractures or by breccia or fault gouge. A fault zone may be as wide as hundreds of meters. (AGI, 1972)

Focus (Seism) - That point within the Earth which is the center of an earthquake and the origin of its elastic waves. Syn: hypocenter; seismic focus; centrum (see Introduction). (AGI, 1972)

Ground Response - A general term referring to the response of earth materials to the passage of earthquake vibration. It may be expressed in general terms (maximum acceleration, dominant period, etc.), or as a ground-motion spectrum.

Hypocenter - See focus.

Intensity (earthquake) - A measure of the effects of an earthquake at a particular place on human and/or structures. The intensity at a point depends not only upon the strength of the earthquake, or the earthquake magnitude, but also upon the distance from the point to the epicenter and the local geology at the point. (AGI, 1972)

Isoseismal line - A line connecting points on the Earth's surface at which earthquake intensity is the same. It is usually a closed curve around the epicenter. Syn: isoseism; isoseismic line; isoseismal. (AGI, 1972)

Liquefaction - A sudden large decrease in the shearing resistance of a cohesionless soil, caused by a collapse of the structure by shock or strain, and associated with a sudden but temporary increase of the pore fluid pressure. (AGI, 1972)

Macroseismic data - Used herein to describe instrumentally recorded earthquakes generally in the range of Richter magnitude 3.0 or more. (This use differs from the AGI definition of "macroseismic observations").

Magnitude (earthquake) - A measure of the strength of an earthquake or the strain energy released by it, as determined by seismographic observations. As defined by Richter, it is the logarithm, to the base 10, of the amplitude in microns of the largest trade deflection that would be observed on a standard torsion seismograph (static magnification = 2800; period = 0.8 sec; damping constant = 0.8) at a distance of 100 kilometers from the epicenter. (AGI, 1972)

Microseismic data - Used herein to describe instrumentally recorded earthquakes generally in the range of Richter magnitude 3.0 or less. (This use is consistent with the AGI definition of microseism and microseismometer, but is more restricted than their definition of microseismic data).

Natural period - The period at which maximum response of a system occurs. The inverse of resonant frequency.

Normal fault - A fault in which the hanging wall appears to have moved downward relative to the footwall. The angle of the fault is usually 45-90 degrees. This is dip-separation, but there may or may not be dip-slip. (AGI, 1972)

Predominant period - The period of the acceleration, velocity or displacement which predominates in a complex vibratory motion. In the analysis of earthquake vibrations, predominant period is normally the period of the maximum amplitude of the acceleration spectrum.

Response spectrum - An array of the response characteristics of a structure or structures ordered according to period or frequency. The structures are normally single-degree-of-freedom oscillators, and the characteristics may be displacement, velocity or acceleration (see Introduction).

Seiche - All standing waves on any body of water whose period is determined by resonant characteristics of the containing basin as controlled by its physical dimensions. (U.S. Geol. Survey Prof. Paper 544-E)

Seismic seiche - Standing waves set up on rivers, reservoirs, ponds and lakes at the time of passage of seismic waves from an earthquake. (U.S. Geol. Survey Prof. Paper 544-E)

Shear - A strain resulting from stresses that cause or tend to cause contiguous parts of a body to slide relatively to each other in a direction parallel to their plane of contact; specifically, the ratio of the relative displacement of these parts to the distance between them. (AGI, 1972)

Shear wave or S-wave - That type of seismic body wave which is propagated by a shearing motion of material so that there is oscillation perpendicular to the direction of propagation. It does not travel through liquids. (AGI, 1972)

Slip - On a fault, the actual relative displacement along the fault plane of two formerly adjacent points on either side of the fault. Slip is three dimensional, whereas separation is two dimensional. (AGI, 1972)

Strike-slip fault - A fault, the actual movement of which is parallel to the strike (trend) of the fault. (AGI, 1972)

Subsidence - A local mass movement that involves principally the gradual downward settling or sinking of the solid Earth's surface with little or no horizontal motion and that does not occur along a free surface (not the result of a landslide or failure of a slope. (AGI, 1972)

Tectonic - Of or pertaining to the forces involved in, or the resulting structures or features of the upper part of the Earth's crust. (mod. from AGI, 1972)

Tsunami - A gravitational sea wave produced by any large-scale, short-duration disturbance of the ocean floor, principally by a shallow submarine earthquake, but also by submarine earth movement, subsidence, or volcanic eruption, characterized by great speed of propagation (up to 950 km/hr.), long wavelength (up to 200 dm.), long period (5 min. to a few hours, generally 10 - 60 min.), and low observable amplitude on the open sea, although it may pile up to great heights (30 m. or more) and cause considerable damage on entering shallow ater along an exposed coast, often thousands of kilometers from the source. (AGI, 1972)

Unconsolidated material - A sediment that is loosely arranged or unstratified or whose particles are not cemented together, occurring either at the surface or at depth. (AGI, 1972)

Water table - The surface between the zone of saturation and the zone of aeration; that surface of a body of unconfined ground water at which the pressure is equal to that of the atmosphere. (AGI, 1972)

APPENDIX B

Earthquake Safety Procedures

EARTHQUAKE SAFETY PROCEDURES

Before an Earthquake

1. Potential earthquake hazards in the home should be removed or corrected. Top-heavy objects and furniture, such as bookcases and storage cabinets, should be fastened to the wall and the largest and heaviest objects placed on lower shelves. Water heaters and other appliances should be firmly bolted down, and flexible connections should be used whenever possible.

2. Supplies of food and water, flashlight, a first-aid kit, and a battery-powered radio should be set aside for use in emergencies. Of course, this is advisable for other types of emergencies, as well as for earthquakes.

3. One or more members of the family should have a knowledge of first aid procedures because medical facilities nearly always are overloaded during an emergency or disaster, or may themselves be damaged beyond use.

4. All responsible family members should know what to do to avoid injury and panic. They should know how to turn off the elctricity, water, and gas; they should know the locations of the main switch and valves. This is particularly important for teenagers who are likely to be alone with smaller children.

5. It is most important for a resident of California to be aware that this is "earthquake country" and that earthquakes are most likely to occur again where they have occurred before. Building codes that require earthquake-resistant construction should be vigorously supported and, when enacted into law, should be rigorously enforced. If effective building codes and grading ordinances do not exist in your community, support their enactment.

During An Earthquake

1. The most important thing to do during an earthquake is to remain calm. If you can do so, you are less likely to be injured. If you are calm, those around you will have a greater tendency to stay calm, too. Make no moves or take no action without thinking about the possible consequences. Motion during an earthquake is not constant; commonly, there are a few seconds between tremors.

2. If you are inside a building, stand in a strong doorway or get under a desk, table, or bed. Watch for falling plaster, bricks, light fixtures, and other objects. Stay away from tall furniture, such as china cabinets, bookcases, and shelves. Stay away from windows, mirrors, and chimneys. In tall buildings, it is best to get under a desk if it is securely fastened to the floor, and to stay away from windows or glass partitions.

3. Do not rush outside. Stairways and exits may be broken or may become jammed with people. Power for elevators and escalators may have failed. Many of the 115 persons who perished in Long Beach and Compton in 1933 ran outside only to be killed by falling debris and collapsing chimneys. If you are in a crowded place such as a theater, athletic stadium, or store, do not rush for an exit because many others will do the same thing. If you must leave a building, choose your exit with care and, when going out, take care to avoid falling debris and collapsing walls or chimneys.

4. If you are outside when an earthquake strikes, try to stay away from high buildings, walls, power poles, lamp posts, or other structures that may fall. Falling or fallen electrical power lines must be avoided. If possible, go to an open area away from all hazards but do not run through the streets. If you are in an automobile, stop in the safest possible place, which, of course, would be an open area, and remain in the car.

After An Earthquake

1. After an earthquake, the most important thing to do is to check for injuries in your family and in the neighborhood. Seriously injured persons should not be moved unless they are in immediate danger of further injury. First aid should be administered, but only by someone who is qualified.

2. Check for fires and fire hazards. If damage has been severe, water lines to hydrants, telephone lines, and fire alarm systems may have been broken; contacting the fire department may be difficult. Some cities, such as San Francisco, have auxiliary water systems and large cisterns in addition to the regular system that supplies water to fire hydrants. Swimming pools, creeks, lakes, and fish ponds are possible emergency sources of water for fire fighting.

3. Utility lines to your house - gas, water, and electricity - and appliances should be checked for damage. If there are gas leaks, shut off the main valve which is usually at the gas meter. Do not use matches, lighters, or open-flame appliances until you are sure there are no gas leaks. Do not use electrical switches or appliances if there are gas leaks, because they give off sparks which could ignite the gas. Shut off the electrical power if there is damage to the wiring; the main switch usually is in or next to the main fuse or circuit breaker box. Spilled flammable fluids, medicines, drugs, and other harmful substances should be cleaned up as soon as possible.

4. Water lines may be damaged to such an extent that the water may be off. Emergency drinking water can be obtained from water heaters, toilet tanks, canned fruits and vegetables, and melted ice cubes. Toilets should not be flushed until both the incoming water lines and outgoing sewerlines have been

checked to see if they are open. If electrical power is off for any length of time, plan to use the foods in your refrigerator and freezer first before they are spoiled. Canned and dried foods should be saved until last.

5. There may be much shattered glass and other debris in the area, so it is advisable to wear shoes or boots and a hard hat if you own one. Broken glass may get into foods and drinks. Liquids can be either strained through a clean cloth such as a handkerchief or decanter. Fireplaces, portable stoves, or barbecues can be used for emergency cooking but the fireplace chimney should be carefully checked for cracks and other damages before being used. In checking the chimney for damage, it should be approached cautiously, because weakened chimneys may collapse with the slightest of aftershocks. Particular checks should be made of the roof line and in the attic because unnoticed damage can lead to a fire. Closets and other storage areas should be checked for objects that have been dislodged or have fallen, but the doors should be opened carefully because of objects that may have fallen against them.

6. Do not use the telephone unless there is a genuine emergency. Emergencies, and damage reports, alerts, and other infomation can be obtained by turning on your radio. Do not go sightseeing; keep the streets open for the passage of emergency vehicles and equipment. Do not speculate or repeat the speculations of other - this is how rumors start.

7. Stay away from beaches and other waterfront areas where seismic sea waves (tsunamis), sometimes called "tidal waves", could strike. Again, your radio is the best source of information concerning the likelihood that a seismic sea wave will occur. Also stay away from steep landslide-prone areas if possible, becuase aftershocks may trigger a landslide or avalnche, especially if there has been a lot of rain and the ground is nearly saturated. Also stay away from earthquake-damaged structures. Additional earthquake shocks known as "aftershocks" normally occur after the main shock, sometimes over a period of several months. These are usually smaller than the main shock but they can cause damage, too, particularly to damaged and already weakened structures.

8. Parents should stay with young children who may suffer psychological trauma if parents are absent during the occurrence of aftershocks.

9. Cooperate with all public safety and relief organizations. Do not go into damaged areas unless authorized; you are subject to arrest if you get in the way of, or otherwise hinder, rescue operations. Martial law has been declared in a number of earthquake disasters. In the 1906 disaster in San Francisco, several looters were shot.

10. Send information about the earthquake to the Seismological Field Survey to help earth scientists understand earthquakes better.

APPENDIX C

Summary of Significant Court Decisions and Legislation

Summary of Significant Court Decisions and Legislation

(Source: Urban Geology Master Plan for California, 1973)

In recent years there have been many attempts by government to reduce losses from geologic hazards. The following summaries are some of the more important ones.

COURT DECISIONS

1. Sheffet decision (Los Angeles Superior Court Case No. 32487): Declared that a public entity is liable for damages to adjacent property resulting from improvements planned, specified or authorized by the public entity in the exercise of its governmental power. (The State Supreme Court refused to rehear this decision, which establishes a judicial precedent.)

2. L.A. County Superior Court (Case No. 684595 and consolidated cases): This decision found the County liable for damages which may have resulted from roadwork and the placement of fill by the County. This case was in regard to the Portuguese Bend landslide, Palos Verdes Hills, Los Angeles County, California.

3. City of Bakersfield vs Miller (48 Cal. Rptr. 889), heard in the State Supreme Court 1966: This decision affirms that the city may declare an older structure not in compliance with the newly adopted Uniform Building Code to be a public nuisance. Further, the city may enforce abatement of the non-conforming condition even though to do so may require the building to be demolished.

4. Burgess vs. Conejo Valley Development Co. (Connor vs. Great Western Savings and Loan Association) (73 Cal. Rptr. 369) heard in the State Supreme Court in 1968, concerning damage to tract homes from expansive soil in Thousand Oaks, Ventura County: This decision affirmed that the home buyer, both first buyer and all subsequent ones, has the right to protection from negligent construction practice leading to damage. In this case, neither contractor, county inspectors, nor representatives of the major lending institution acted to ascertain expansive soil conditions, or to prevent damage from them.

5. Oakes vs. The McCarthy Co. (California Appellate Reports, 2d Series, 267, 1968) the court held that in the Palos Verdes area, Los Angeles County, a developer and soils engineering company could be liable in negligence for damages to a home resulting from using improper (clay) fill material and improperly compacting that fill so that earth movement resulted. Also, the court awarded punitive damages against the developer for fraudulent conceal-

ment of material facts concerning the property, i.e., failure to volunteer to the prospective buyer that the house was built upon fill.

LEGISLATION

PUBLIC RESOURCES CODE

Section 660-662 and 2621-2625: These sections require the State Geologyst to delienate special studies zones encompassing potentially and recently active fault traces. It requires cities and counties to exercise specified approval authority with respect to real estate developments or structures for human occupancy within such delineated zones.

Section 2700-2708: These sections require the Division of Mines and Geology to purchase and install strong-motion instruments (to measure the effects of future earthquakes) in representative structure and geologic environments throughout the state.

Section 2750: Establishes a state mining and minerals policy which, among other things, encourages wise use of mineral resources.

EDUCATION CODE

Section 15002.1: This section requires that geological and soils engineering studies by conducted on all new school sites and on existing sites where deemed necessary by the Department of General Services.

Section 15451-15466: These sections constitute the Field Act and require that public schools be designed for the protection of life and property. These sections, enacted in 1933 after the Long Beach earthquake, are enforced by the State Office of Architecture and Construction in accordance with regulations contained in Title 21 of the California Administrative Code.

HEALTH AND SAFETY CODE

Sections 15000 et seq.: These sections require that geological and engineering studies by conducted on each new hospital or additions affecting the structure on an existing hospital, excepting therefrom one story Type V buildings 4000 sq. ft. or less in area.

Sections 19100-19150: These sections constitute the Riley Act and require certain buildings to be constructed to resist lateral forces, specified in Title 24 California Administrative Code.

Section 17922, 17951-17958.7: These sections require cities and counties to adopt and enforce the Uniform Building Code, including a grading section (chap. 70), a minimum protection against some geologic hazards.

BUSINESS AND PROFESSIONAL CODE

Section 7800-7887: These sections provide for the registration of geologists and geophysicists, and the certification of certain geologists in the specialty of engineering geology.

Section 11010: This section requires that a statement of the soil conditions be prepared and needed modifications be carried out in accordance with the recommendations of a registered civil engineer.

Section 11100-11629: These sections require studies in subdivisions to evaluate the possibilities of flooding and unfavorable soils.

GOVERNMENT CODE

Section 8589.5: This section requires that inundation maps and emergency evacuation plans be completed for areas subject to inundation by dam failure.

Section 65300-65302.1: These sections require that each city and county shall adopt the following elements:

Seismic Safety Element consisting of the identification and appraisal of seismic hazards including an appraisal of landsliding due to seismic events.

Conservation element including the conservation, development and utilization of minerals.

Safety element including protection of the community from geologic hazards including mapping of know geologic hazards.

CITY OF ALAMEDA

SEISMIC SAFETY ELEMENT

A PART OF THE GENERAL PLAN
SAFETY ELEMENT

TECHNICAL SECTION

Prepared by

ENVICOM CORPORATION

ADOPTED BY CITY COUNCIL, SEPTEMBER 21, 1976

Table of Contents

Table of Contents (Cont.)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF TABLES

I. INTRODUCTION

A. SCOPE OF INVESTIGATION

Section 65302 (f) of the Government Code requires a Seismic Safety Element of all city and county general plans as follows:

> "A seismic safety element consisting of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to the effects of seismically induced waves such as tsunamis and seiches.
>
> The seismic safety element shall also include an appraisal of mudslides, landslides and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards such as possible surface ruptures from faulting, groundshaking, ground failure and seismically induced waves."

The Guidelines (California Council on Intergovernmental Relations, 1973) for the preparation of local general plans states that:

> "The intent is that <u>all</u> seismic hazards are to be considered, event though only ground and water effects are given as specific examples. The basic objective is to reduce loss of life, injuries, damage to property, and economic and scoial dislocations resulting from future earthquakes."

Based on the interpretation of the intent of the law, the Guidelines define the scope of the Element as including:

1. A general policy statement.
2. The identification, delineation and evaluation of natural seismic hazards.
3. The consideration of existing structural hazards.
4. An evaluation of disaster planning program.
5. The determination of specific land use standards related to level of hazard and risk.

The Guidelines indicate that the identification of natural seismic hazards should include the following:

"1. General structural geology and geologic history.

2. Location of all active or potentially active faults, with evaluation regarding past displacement and probability of future movement.

3. Evaluation of slope stability, soils subject to liquefaction and differential subsidence.

4. Assessment of potential for the occurrence and severity of damaging ground shaking and amplifying effects of unconsolidated materials.

5. Identification of areas subject to seiches and tsunamis.

6. Maps identifying location of the above characteristics."

The following technical evaluation is intended to meet or exceed these requirements.

B. PHILOSOPHY OF THE ANALYSIS

The quantitative study of the strong shaking of earthquakes is a relatively young science. It was begun in California in the early 1930's, but has been limited by the necessity of having the right instruments in the right place when a significant earthquake does occur. Much information has been acquired over the last 40 years, but there are significant gaps and much remains to be learned.

With this relatively limited level of basic data, two different approaches to the development of a Seismic Safety Element are available. One can utilize broad generalizations to describe expected events; certainly the inadequacies of the data favor this approach. On the other hand, if the results are to be used by engineers in designing safer structures, then a commitment to mathematical form is necessary. To this end, the analysis is developed in this way, whenever possible, and presented in chart or graph form. Qualitative descriptions of the results are included for the lay reader, and a brief discussion of methodology, terminology, and concepts is included in Section C. A Glossary of Terms for reference purposes is included at the back of the report.

The basic philosophy within which this analysis has been developed is that the intent of the Seismic Safety Element is to plan and prepare for the future based on what we know today rather than waiting until we know all that we would like to know.

C. CONCEPTS, METHODOLOGY, AND TERMINOLOGY

1. General Statement

The Seismic Safety Element is probably the most technically-oriented of all the mandated elements of the General Plan. For this reason, and because of the wide range of backgrounds and experience of expected readers, it is appropriate to include in the Introduction a discussion of concepts, methodology, and terminology to be used in developing the technical base for this element. This discussion is intended to supply not only a dictionary function of technical terms and concepts, but, most importantly, to establish the systematic cause and effect relationships between the several seismic hazards, and the need for a systematic analysis of available information.

The topics discussed in the following sections of the introduction are arranged in an order that becomes increasingly more difficult for the layman. Sections 2 through 4 discuss concepts and terms commonly included in newspaper accounts of earthquakes, while later sections discuss the concepts necessary in the technical analysis of earthquake hazards. The latter are intended primarily for readers with engineering or scientific backgrounds, but may also be of interest to the lay reader.

The text of the report is arranged in a similar order. Each section becomes increasingly more complex, and the later sections are intended to document the analysis for engineers and earth scientists who may wish to expand on or apply the data to the detailed analysis of individual sites.

2. Types of Hazards

The several seismic hazards discussed in the C.I.R. Guidelines can be grouped as a cause-and-effect classification that is the basis for the order of their consideration. Earthquakes originate as the shock wave generated by movement along an active fault. The primary natural hazards are ground shaking and the potential for ground rupture along the surface trace of the fault. Secondary natural hazards result from the interaction of ground shaking with existing ground instabilities, and include liquefaction, settlement and landslides. In this context, tsunamis, or "tidal waves", and seiches would be primary natural hazards.

The potentially damaging natural events (hazards) discussed above may interact with man-made structures. If the structure is unable to accommodate the natural event, failure will occur. The potential for such failure is termed a structural hazard, and includes not only the structures themselves, but also the potential for damage or injury that could occur as the result of movement of loose or inadequately restrained objects within, on, or adjacent to, a structure.

3. Active Faults - The Source of Earthquakes

Earth scientists are generally agreed that earthquakes originate as the result of an abrupt break or movement of the rock in the relatively brittle crust of the earth. The earthquake is the effect of the shock waves generated by the break, much the same as sound waves (a noise) are generated by breaking a brittle stick. If the area of the break is small and limited to the deeper part of the crust, the resulting earthquake will be small. However, if the break is large and extends to the surface, then the break can result in a major earthquake.

These breaks in the earth's crust are called faults. In California, faults are extremely common, and vary from the small breaks of an inch or less that can be seen in almost any roadcut, to the larger faults such as the San Andreas on which movement over many millions of years has amounted to hundreds of miles. In addition to the size of faults, their "age" is also important. Many large faults have not moved for millions of years; they are considered "dead" or no longer active. They were probably the source of great earthquakes millions of years ago, but are not considered dangerous today.

Since faults vary as to the likelihood of their being the source of an earthquake, considerable effort has, and is continuing to be, expended by geologists and seismologists to determine and delineate the faults likely to generate significant earthquakes. The C.I.R. Guidelines define an active fault as one that "has moved in recent geologic time and which is likely to move again in the relatively near future. Definitions for planning purposes extend on the order of 10,000 years or more back and 100 years or more forward." In this definition, "has moved" would normally be taken to mean demonstrable movement at the surface.

The State Mining and Geology Board (1973), for purposes of the Alquist-Priolo Geologic Hazards Zone Act (Chapter 7.5, Division 2, Public Resources Code, State of California), "regards faults which have had surface displacement within Holocene time (about the last 11,000 years) as active and hence as constituting a potential hazard."

The State Geologist (Slosson, 1973, Explanation of Special Studies Zones Maps, p.3 & 4) defines a potentially active fault as one "considered to have been active during Quaternary time (last 3,000,000 years) -- on the basis of evidence of surface displacement." The State Geologist knows the contrast with the State Mining and Geology Board, but also states: "An exception is a Quaternary fault which is determined, from direct evidence, to have become inactive before Holocene time (last 11,000 years)."

The definitions above are compatible if taken in the following sequence:

1. A potentially active fault is one which exhibits evidence of surface displacement during Quaternary time (last 3,000,000 years approximately).

2. A potentially active fault will be considered as an active fault if there is evidence of surface displacement during Holocene time (last 11,000 years, approximately).

3. A potentially active fault will be considered as inactive if, by direct evidence, it can be shown that there has been no displacement during Holocene time.

The key to the practical application of the above definitions is the placement of the burden of proof. The State Geologist will consider a fault as potentially active if there is evidence of surface displacement during Quaternary time. If a fault is so designated as required by the Alquist-Priolo Act, then the burden of proof shifts to the developer to show by "direct evidence" that the fault has not been active (i.e. no surface displacement) during Holocene time. The practical application of this system of evaluation will depend primarily on the interpretation of "direct evidence" in the review and evaluation of the required geologic reports.

The above discussion applies directly to Special Studies Zones as required by the Alquist Priolo Act. To date, no such zones have been established within the study area. However, the State Geologist is required to "continually review zones and to delineate additional zones. In this context, evidence of fault activity in the study area will be discussed herein utilizing the framework of evaluation as provided by the State Geologist and the State Mining and Geology Board. Additional comment on the responsibility for evaluation of geology/seismic hazards is included in Section D of this Introduction, and also as pertinent in that part of the text covering the evaluation of active and potentially active faults.

4. Describing an Earthquake

Several terms are used to describe the location, "size", and effects of an earthquake. A clear understanding of the meaning of these terms and their limitations is essential to an understanding of the results of the investigation.

The location of an earthquake is generally given as the epicenter of the earthquake. This is a point on the earth's surface vertically above the hypocenter or focus of the quake. The latter is the point from which the shock waves first emanate. However, as discussed above, earthquakes originate from faults. These are surfaces, not points, so the hypocenter is only one point on the surface that is the source of the earthquake.

Magnitude describes the size of the earthquake itself. Technically it is defined as the log of the maximum amplitude as recorded on a standard seismograph at 100 kilometers (62 miles) from the epicenter. The most important part of this definition is that it is a log scale; that is, an increase of 1 on the magnitude scale (e.g. magnitude 5.0 to 6.0) represents an increase of 10 in the amplitude of the recorded wave.

Intensity describes the degree of shaking in terms of the damage at a particular location. The scale used today is the Modified Mercalli Scale of 1931, and is composed of 12 categories (I to XII) of damage as described in Table 1. The Roman numerals are used to emphasize that the units in the scale are discrete categories rather than a continuous numerical sequence as is the magnitude scale. It is important to remember that intensity is a very general description of the effects of an earthquake, and depends not only on the size of the quake and the distance to its center, but also on the quality of the construction that has been damaged and the nature of local ground conditions.

5. Occurrence, Recurrence and Risk of Earthquakes

Earthquakes have had in the past a certain occurrence in space and time. These occurrences may or may not set certain patterns that can form the basis for predicting their occurrence in the future. When such occurrences are analyzed in time, certain characteristics may statistically recur at definite intervals. If it can be shown that a particular magnitude earthquake recurs on a fault on the average of once in a certain time interval, then that interval is said to be the recurrence interval for that magnitude. Or, if the interval of time is set (e.g. a 100-year period), then earthquakes of a particular magnitude may recur a certain number of times in the specified period. This number is then the recurrence rate for that magnitude.

In California small earthquakes occur much more often than large earthquakes. Also, there is a fairly definite pattern in that the log (base 10) of the number of events of a particular magnitude that have occurred in the past is approximately proportional to the magnitude of those events. This relationship appears to apply to larger areas such as California and western Nevada, some smaller areas such as the Los Angeles Basin, the Imperial Valley, etc., and to some faults. However, this relationship does not necessarily apply to all faults, and it should be applied to small areas, such as cities or individual sites, with great care.

Recurrence intervals can be used to indicate the risk of an earthquake in much the same way that recurrence is used to describe the risk of flooding (e.g. 100-year flood). There is one important difference, however. Flood is the result of a

TABLE I. MODIFIED MERCALLI INTENSITY SCALE OF 1931
(from United States Earthquakes)

Intensity	Description of Damage
I	Not felt except by a very few under specially favorable circumstances. (I Rossi-Forel Scale)
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale)
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel Scale)
IV	During the day, felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel Scale)
V	Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale)
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale)
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerably in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars. (VIII Rossi-Forel Scale)
VIII	Damage slight in specially designed structures; considerable in ordinary, substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII to IX Rossi-Forel Scale)
IX	Damage considerable in specially designed structures; well-designed, frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX Rossi-Forel Scale)
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with their foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale)
XI	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII	Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into air.

random combination of meteorological events, whereas current geologic theory indicates that the buildup of the strain released during an earthquake is more likely to be regular. This regularity suggests that prediction, to varying degrees, may be possible depending on the extent of understanding of a particular fault. In some cases this understanding is limited to a statistical regularity in the number and magnitude of earthquakes generated. For others, such as the San Andreas fault, much more is known on which to base an estimate of the risk involved. For others, little more is known other than that there is some degree of hazard involved.

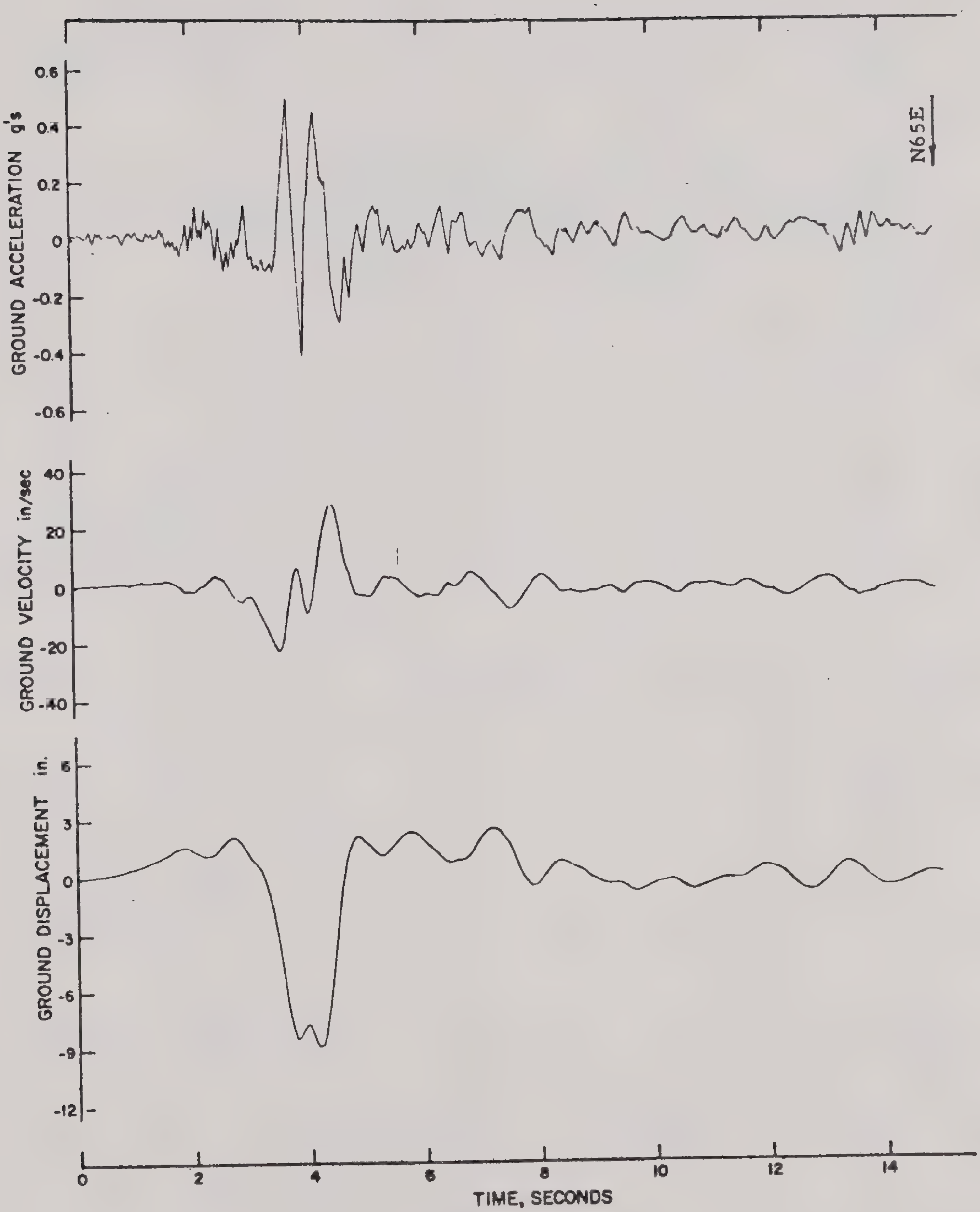
6. Acceleration, Velocity and Displacement

The data of the seismologist and geologist are, in general, not applicable to the engineering design of earthquake-resistant structures. The seismograph, for example, is a very sensitive instrument designed to record earthquakes at great distances. A level of shaking that would be meaningful to an engineer in designing a building would put most seismographs completely off-scale.

As a result, it has been necessary to design and install special instruments to record the strong motions of earthquakes that are of interest to the engineer in the design of earthquake-resistant structures. The first such instruments, principally accelerographs and seismoscopes, were installed by the U.S. Coast and Geodetic Survey in the late 1920's. Since that time, the instrumentation and analytical techniques have been continuously improved, and many excellent records have been obtained of the more recent strong earthquakes.

The following sections are a brief introduction to the concepts, data, and application of strong-motion records. The science is relatively young, and is growing in bursts that follow the recording of a damaging earthquake.

The accelerograph is a short-period instrument (in contrast to the seismograph), and measures the acceleration of the ground or the structure on which it is mounted. Figure 1 shows the ground acceleration recorded just a few hundred feet from the slipped fault during the 1966 Parkfield earthquake. The velocity and displacement curves have been derived from it by integration. It is a particularly good example of the relationships of these three parameters of motion because of the relatively "clean", single-displacement pulse that corresponds to two velocity peaks and four acceleration peaks. Figure 2 shows the more typically complex record of the San Fernando earthquake as recorded at Pacoima Dam. Neither of the two, however, are typical records in terms of accelerations recorded. The Pacoima record shows the largest acceleration recorded to date (1.25g), and the Parkfield record (0.5g) was the largest recorded in the United States before the San Fernando earthquake.



Station 2 N65E Motion.

from Housner & Trifunac, 1967

Figure 1. Ground acceleration, velocity, and displacement. 1966 Parkfield earthquake.

from Housner & Trifunac, 1967.

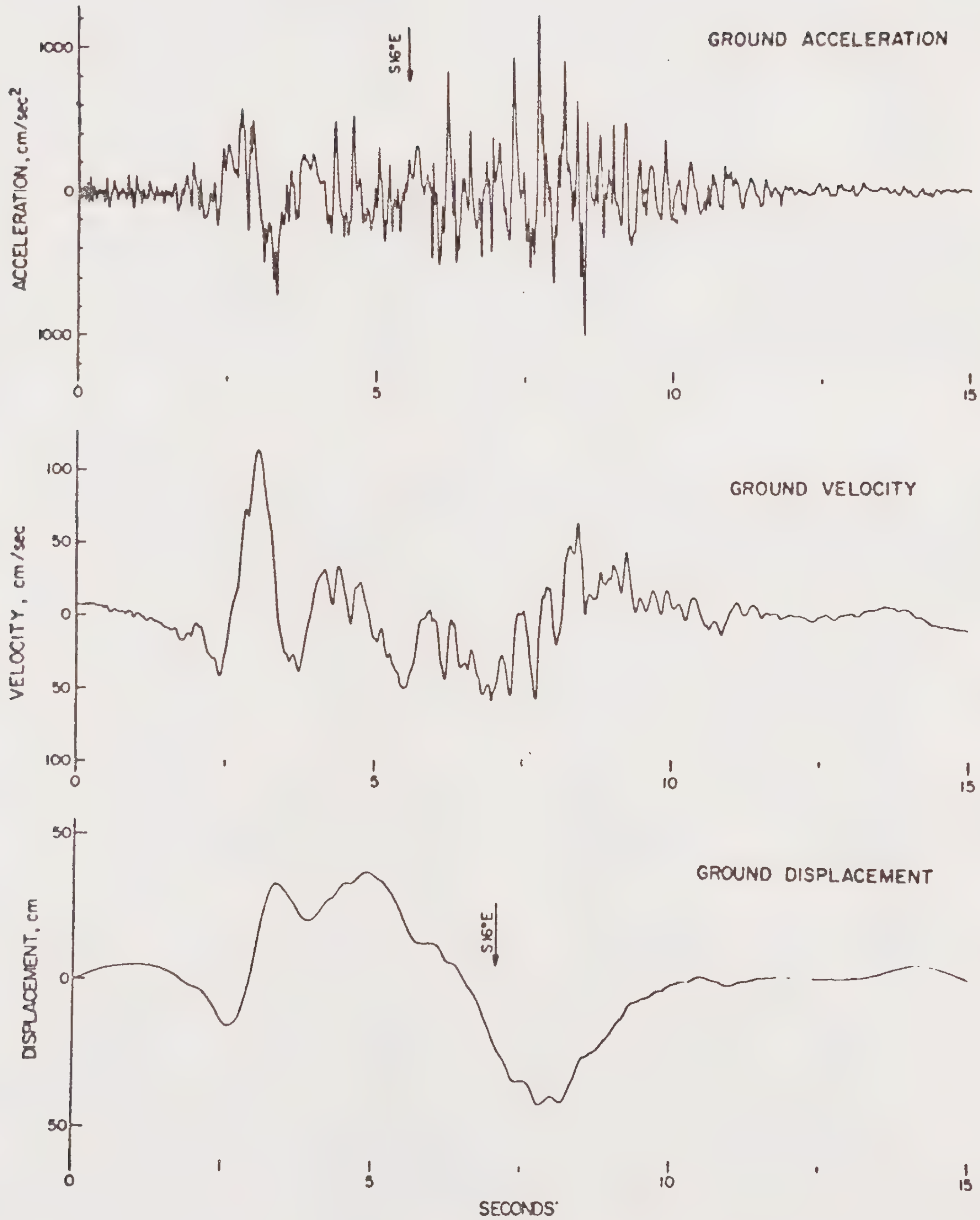


Figure 2. Acceleration, velocity and displacement in the S16°E direction during the main event of the San Fernando earthquake of February 9, 1971, 06:00 (PST).

from Trifunac & Hudson, 1971.

It should also be noted that accelerographs normally record three components; two in the horizontal plane at a right angle to each other, and one vertical. Only one component is shown in each of the two examples.

Maximum acceleration is one of the basic parameters describing ground shaking, and has been the one most often requested by agencies such as FHA in determining the earthquake hazard to residential structures. It is particularly important for "low-rise" construction (up to 3 to 5 stories) and other structures having natural periods in the range of 0.3 - 0.5 seconds or less.

7. Frequency Content - Fourier and Response Spectra

The frequency content of the ground motion is particularly important for the intermediate and higher structures. The problem can be compared to pushing a child in a swing. If the pushes are timed to coincide with the natural period of the swing, then each push makes the swing go higher. However, if the timing is not right, then most of the push is lost "fighting" the natural period of the swing. The situation is similar during earthquakes. Structures have certain natural periods of vibration. If the pulses of the earthquake match the natural period of the structure, even a moderate earthquake can cause damaging movement. However, if the match is poor, the movement and resulting damage will be much less.

Two methods are commonly used to analyze and display the frequency content of an earthquake. A Fourier analysis is a common mathematical method of deriving the significant frequency characteristics of a time-signal such as the record of an earthquake. The results of the analysis are an amplitude term and a phase term. The amplitude is normally plotted against the period for the amplitude to give a Fourier amplitude spectrum for the range of frequencies that are of interest. Since the mathematical procedure is basically an integration of acceleration with time, the Fourier amplitude has the units of velocity.

A response spectrum is derived by a similar mathematical process, but is slightly different in concept. It represents the maximum response of a series of oscillators, having particular periods and damping, when subjected to the shaking of the earthquake. The result is also expressed in units of velocity with the particular nomenclature depending on the precise method used to derive the spectrum.

The Fourier spectrum can be generally described as the energy available to shake structures having various natural frequencies. The response spectrum gives the effect, in maximum velocity, of this available energy on simple structures having various frequencies and damping. At zero damping the two are very similar. Figure 3 shows a plot of both the Fourier spectrum and the response spectrum with zero damping for the Taft earthquake of 1952. Figure 4 shows the response spectrum for the Parkfield record (Figure 1) for several levels of damping.

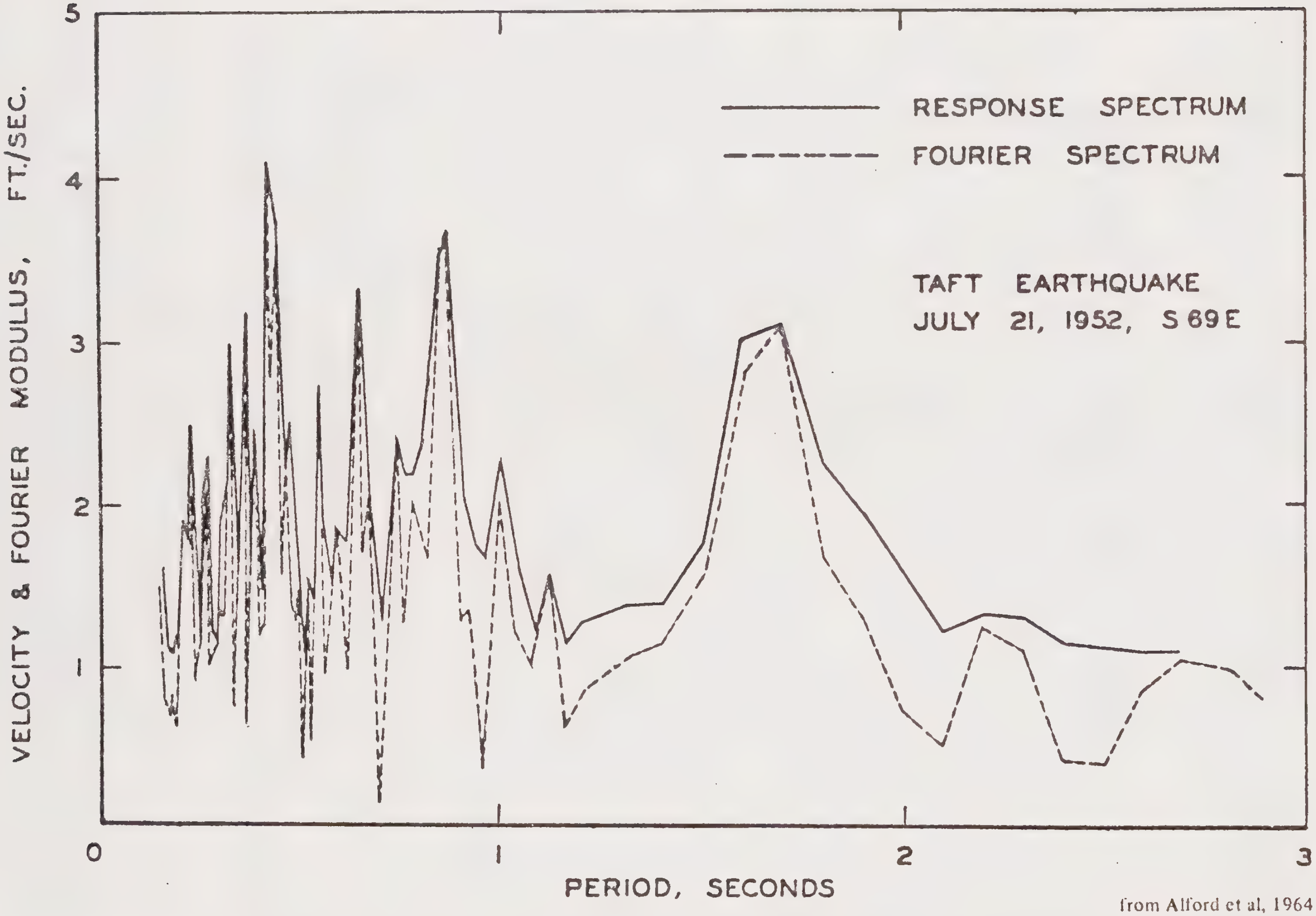


Figure 3. Fourier and response spectra, 1952 Kern County earthquake.
from Alford et al, 1964.

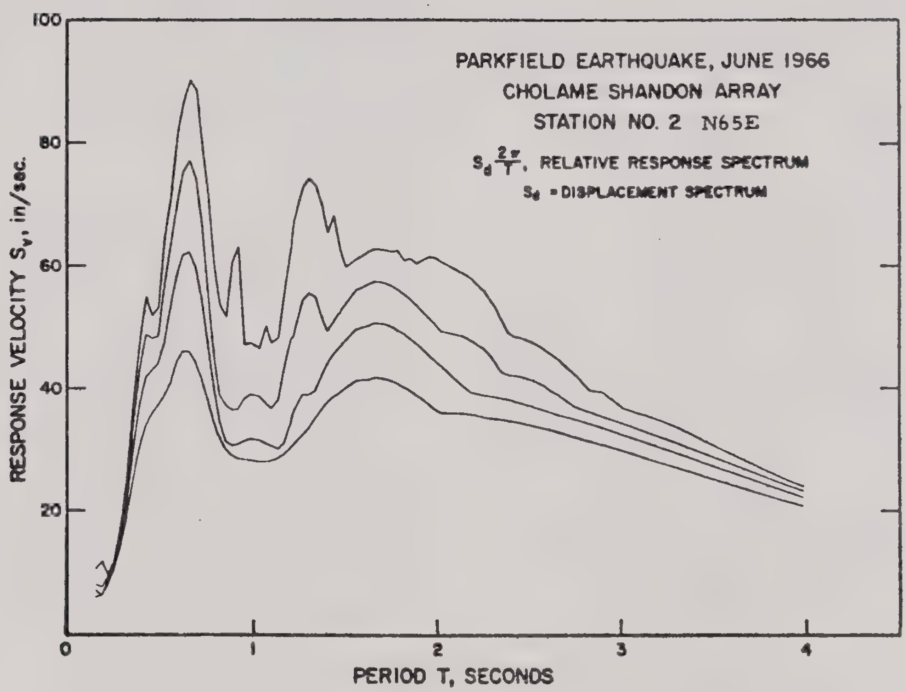


Figure 4. Response spectra, 1966 Parkfield earthquake. The curves are for 0, 2, 5, and 10% damping.

from Housner & Trifunac, 1967.

8. Near-Surface Amplification

The shock waves of an earthquake radiate outward from the source (i.e. the slipped fault) through the deeper and relatively more dense parts of the earth's crust. In this medium, the waves travel at high velocity and with relatively low amplitude. However, as they approach the surface, the velocity of the medium decreases and may become quite variable if layers of different rock types are present. The overall effect is generally an amplification of the wave or of certain frequencies within the spectrum of the wave.

The most consistently applicable effect is the increase in wave amplitude that accompanies the decrease in velocity. This relationship can be compared to laws of mechanics that require the conservation of energy and momentum. In the case of earthquake waves, the energy of velocity is transferred to energy of wave amplitude when the velocity decreases.

A second effect is the amplification of certain frequencies due to the thickness and velocity of near-surface layers of the earth. The geometry of these layers controls the frequency of shaking just like the geometry of a TV antenna controls the frequency it receives best. A striking example is the very high amplification of waves of the 2.5-second period (Figure 5) by the stratification of the old lake beds on which Mexico City has been built. This concentration of the energy in a very narrow frequency range could be disastrous for structures with a matching natural period. Just like the child in the swing, they would move more and more with each successive pulse of the quake. Such pronounced amplifications are unusual, but if present, they can be extremely important.

D. RESPONSIBILITY FOR SEISMIC/GEOLOGIC HAZARD EVALUATION

The responsibility for the evaluation of seismic and geologic hazards lies with both the public and private sectors. The following are suggested as guidelines in determining the distribution of responsibility of the two sectors:

1. The owner or developer of a particular site should be responsible for, and should bear the cost of, the evaluation of those hazards that can be evaluated on or in the near-vicinity of the site.

2. Those hazards that cannot be adequately evaluated at the site should be considered for evaluation with public funds. The nature of the funding may vary depending on the extent of the impact of the hazard.

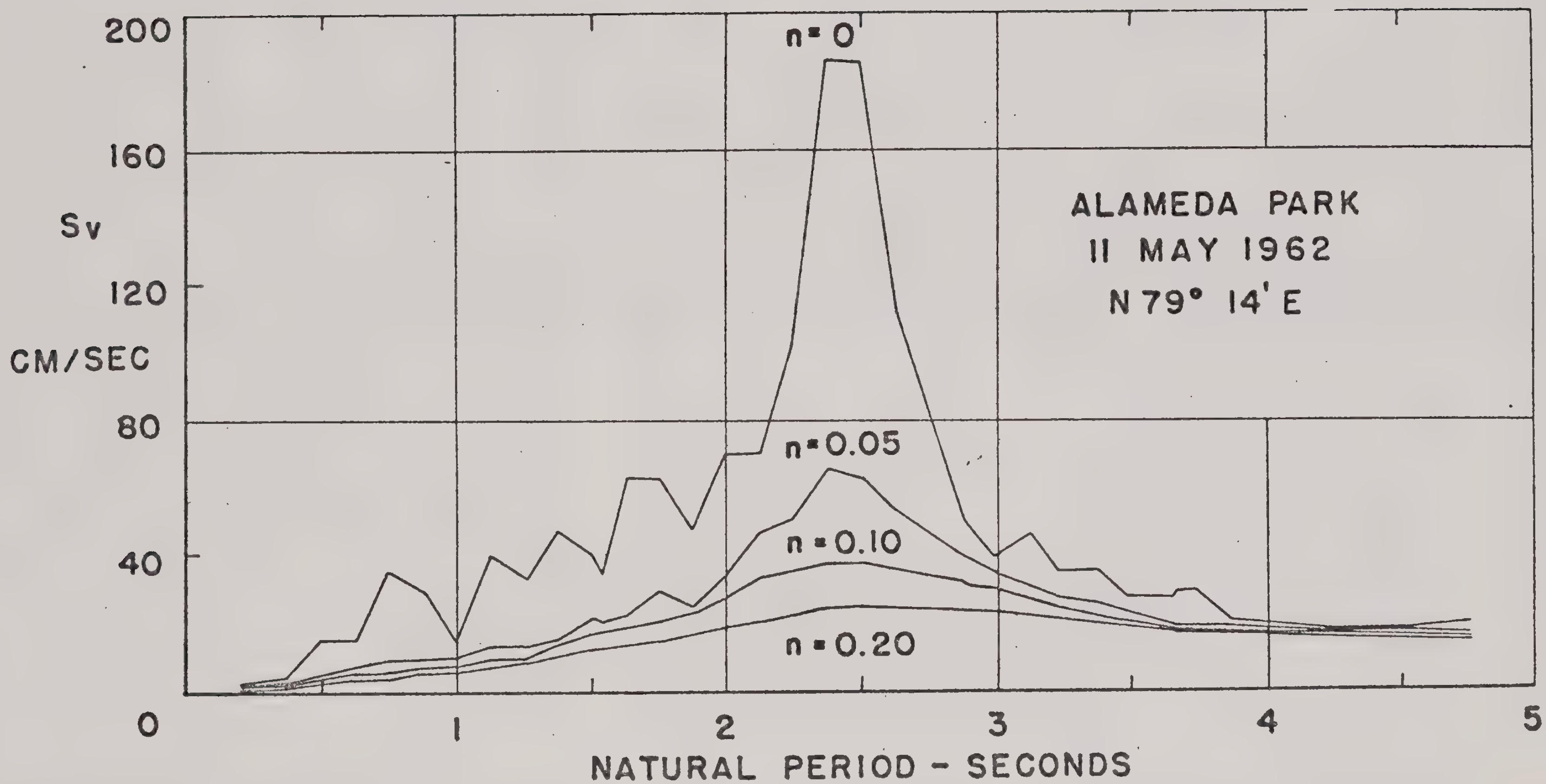


Figure 5. Velocity spectrum, 1962 earthquake near Mexico City.

(See "Mexican Earthquakes of 11 May and 19 May, 1962, *by P.C. Jennings, Earthquake Engineering Research Laboratory, C.I.T.)

3. To facilitate the administration of public safety, it may be desirable to undertake, with public funds, a general evaluation of site-related hazards as they exist within an entire jurisdiction.

The application of these guidelines to geologic/seismic hazards depends on the type of hazard and the availability of information that can be used to evaluate the hazard. For example, faults can be located on a particular site by the engineering geologist during the site investigation. However, the rock formations necessary for evaluation of the activity of the fault are normally present only at certain critical locations, and evaluation of activity may require a publicly funded investigation. On the other hand, landslides can normally be evaluated as part of the site investigation funded by the owner or developer. Public agencies may wish to fund a general investigation of landslide hazards to facilitate the administration of public safety, but the final evaluation must be a part of site evaluation because additional hazard may be introduced by proposed modification of the site.

The distribution of emphasis of this Technical Report is based on these concepts. Those aspects of a particular hazard that cannot be evaluated on a site-basis, or which can more efficiently be evaluated on a regional basis, are emphasized in this analysis. Those hazards that can be effectively evaluated as a part of site investigations are treated in a general way with the intent that the results be used to facilitate the administration of public safety. It should be emphasized that such generalized evaluations should in no way be considered a substitute for a detailed site investigation which must consider not only existing conditions but also any hazards that may result from proposed modifications of the site.

A key step in hazard evaluation is public involvement, through their elected representatives, in the determination of acceptable levels of risk. All hazards involve risk. A technical evaluation may determine certain risk parameters, but only the public can determine the acceptable balance between the risk of a hazard and the cost of mitigation. Because of the extreme importance of this step, primary emphasis is placed on the technical evaluation of available information relating to the risk of seismic hazards. The technical analysis can provide such information, but only the public sector can make the final determination of the acceptability of those risks.

The relationship between the concepts discussed above and the evaluation of specific seismic/geologic hazards is shown in Table 2. The primary responsibility for evaluation of each aspect of a hazard is shown by an "XX", and by an "XXX" if a determination of acceptable risk is involved. Those aspects for which either sector may commonly have a secondary responsibility are indicated by an "X". The intent is to show the distribution of responsibility for evaluation of a hazard; the overall regulatory responsibility of government is not included.

TABLE 2. DISTRIBUTION OF RESPONSIBILITY FOR EVALUATION OF SEISMIC/GEOLOGIC HAZARDS

Hazard	Responsible Sector	
	Public	Private
1. Fault rupture:		
a. Evaluation of fault	XXX	
b. Location at Site		XX
2. Earthquake shaking:		
a. Sources of shaking	XXX	
b. General levels of shaking	XX	X
c. Effects on site		XX
3. Tsunami and seiche:		
a. Risk of occurrence	XXX	
b. Effects on site		XX
4. Dam failure:		
a. Risk of occurrence	XXX	
b. Effects on site		XX
5. Landslide:		
a. Regional evaluation	XX	X
b. Effects on site		XX
6. Liquefaction, settlement, & subsidence		
a. Regional evaluation	XX(1)	
b. Effects on site		XX

X Secondary responsibility
XX Primary responsibility
XXX Primary responsibility including determination of acceptable risk
(1) Evaluation requires determination of expected shaking.

II. SEISMIC SETTING

A. GENERAL

The City of Alameda is located is a seismically active area, and in close proximity to several of the many active and potentially active faults of Central California. This report analyzes the earthquakes that should be expected in the future, and the accompanying effects that should be expected in the study area. For purposes of defining the problem, the principal active faults are shown on Figure 6. While significant earthquakes can and probably will occur on other faults, available evidence indicates that their effects in the City will be less than the effects of earthquakes expected from the faults selected for further analysis.

Figure 7 shows the locations of all earthquake epicenters in the vicinity of Alameda for the period June, 1932 through June, 1973 for which magnitudes were calculated (data from U.C. at Berkeley Seismographic Station). Many more earthquakes actually occurred in this area, but the magnitudes of the smaller events (less than magnitude 3.0) were not calculated in the early years (up to about 1944). Consequently, the number of smaller events shown on the map is not representative of the entire time period.

Important points to note are: 1) the concentration of epicenters in the vicinity of the Hayward fault; and 2) the concentration of epicenters along the San Andreas fault.

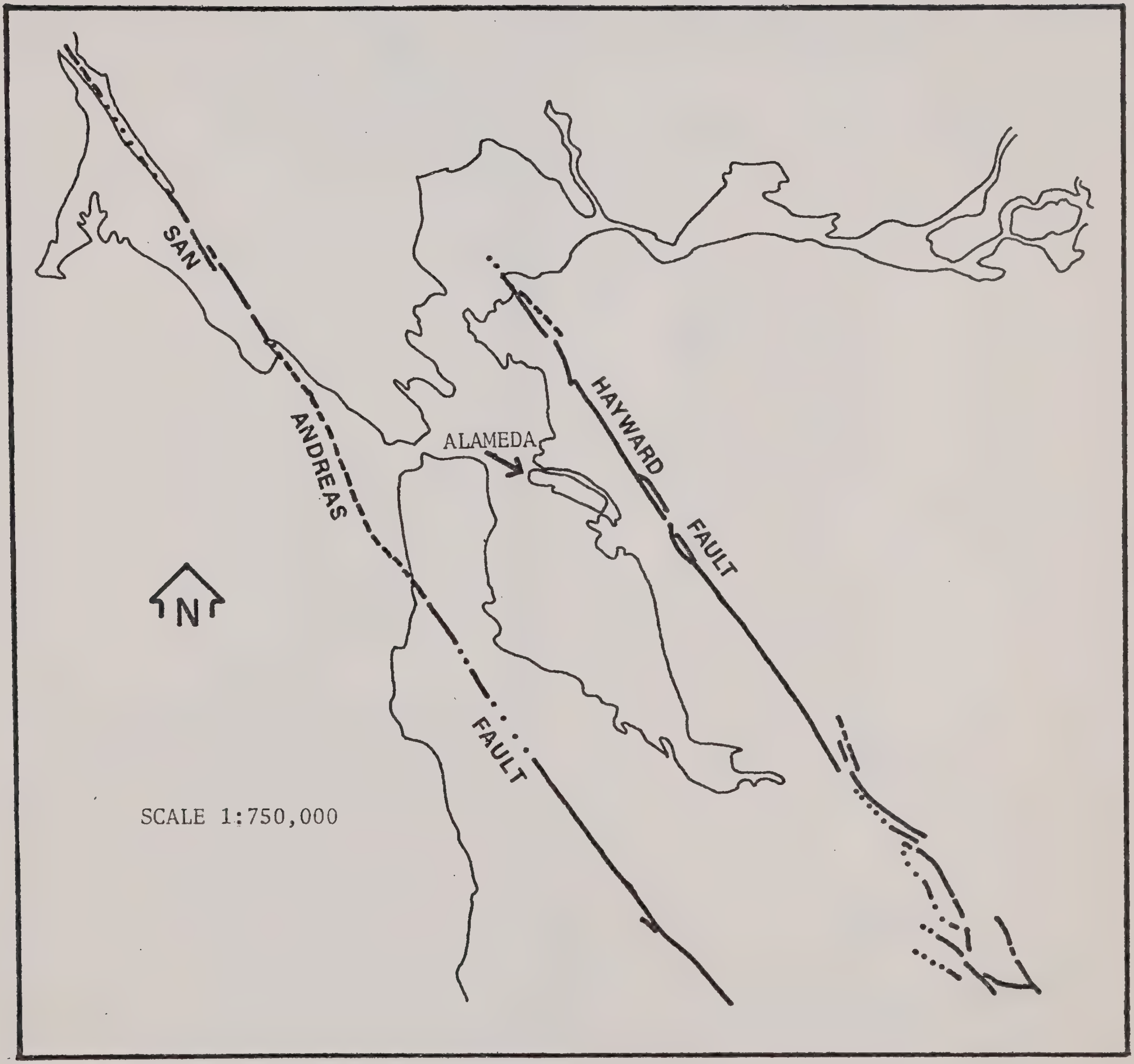


Figure 6. Principal active faults in the Alameda area.

FIGURE 7
EPICENTER MAP
1932-1973

B. GROUNDSHAKING

1. <u>Historical Record</u>

a. San Andreas Fault Zone

The San Andreas fault zone has generated two "great" earthquakes in recorded history: the 1857 Fort Tejon earthquake (magnitude 7.5-8.5), and the 1906 San Francisco earthquake (magnitude 8.3). Ground shaking intensities in the study area were not recorded for the 1857 event, but reached a level of VIII, on the Modified Mercalli Scale (see Introduction), during the 1906 earthquake (Lawson, 1908).

b. Hayward Fault Zone

The Hayward fault zone has been the source of two large earthquakes in recorded history: one in 1836, and the other in 1868. Magnitudes were not assigned to earthquakes at that time, but the extent of surface rupture that occurred with both events suggests that both had magnitudes of the order of 7.0. Intensities assigned in the vicinity of Alameda ranged from VIII to IX on the Modified Mercalli Scale.

2. <u>Predictive Analysis</u>

a. San Andreas Fault

The San Andreas fault zone has been divided by Allen (1968) into several areas of contrasting behavior (Figure 8). The area of particular interest is the segment between Hollister and Cape Mendocino that generated the San Francisco earthquake of 1906. This was one of the three "great earthquakes" of California's historic record, and the major portion of this segment of the fault has not moved since. It is the closest part of

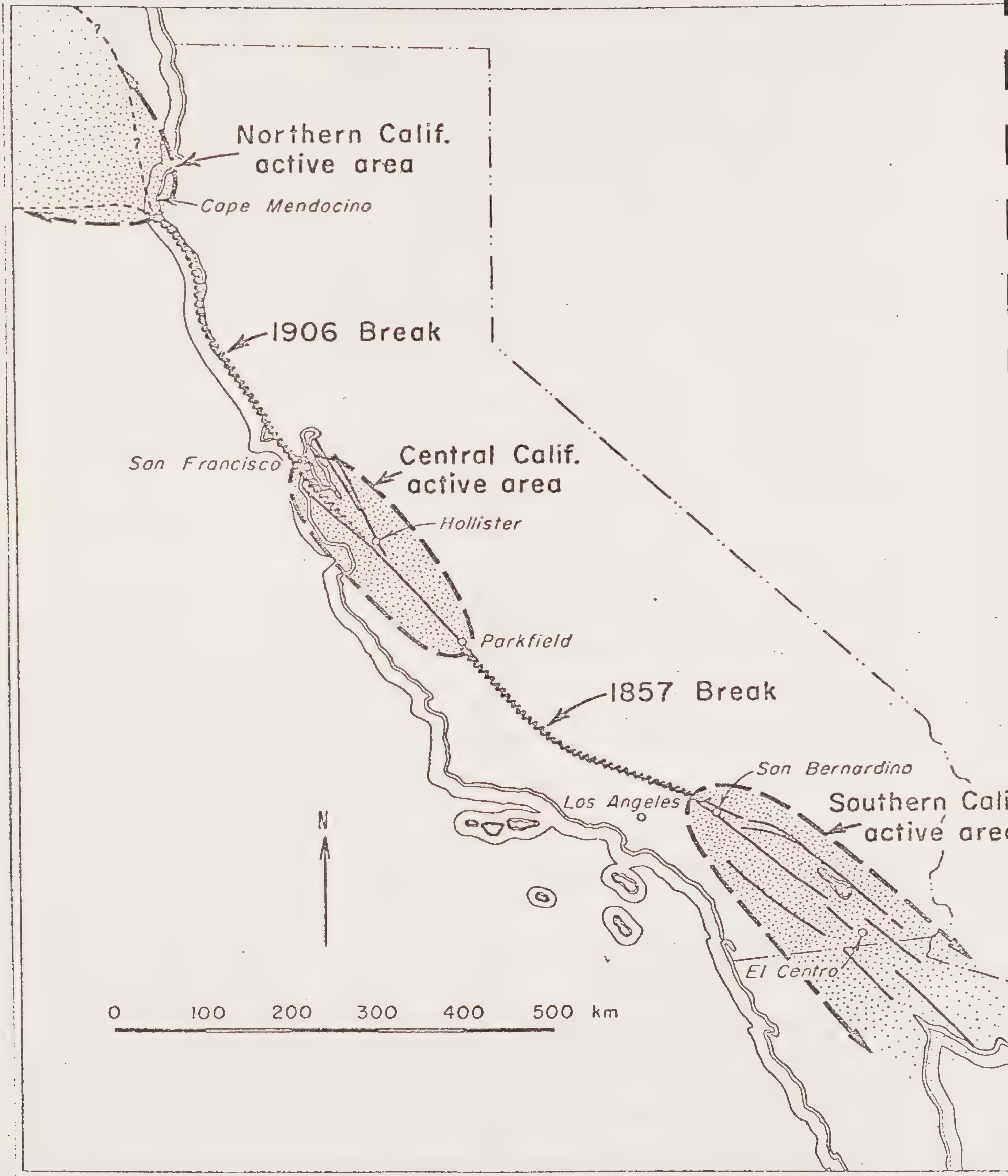


Figure 8 . Areas of contrasting seismic behavior along the San Andreas fault zone in California. From Allen, 1968.

the fault to the study area.

The segments of the fault to the northwest and southeast of the 1906 break are "active areas" that experience earthquakes of medium to small magnitude on a fairly regular basis. The 1906 break, however, is not moving, but is storing energy. The approximate rate of this storage can be deduced by movements within the "Central California Active Area". Survey networks across the fault indicate that movement is occurring at approximately 5-6 cm/year (Greensfelder, 1972) within the active area. No survey measurements are available for the "Northern California Active Area" because most of the area is under water.

The magnitude of the earthquake generated by slip on a fault is approximately proportional to the logarithm of the movement (surface displacement) that occurs. Data on displacement and magnitude compiled by Bonilla (1970) for the San Andreas and faults of similar movement are listed in Table 3 and are plotted on Figure 9. The fitting of a straight line curve to the data is somewhat arbitrary, and in this process the values for the San Andreas itself are given more weight.

TABLE 3
FAULT DISPLACEMENT AND EARTHQUAKE MAGNITUDE
STRIKE-SLIP FAULTS IN CALIFORNIA

	Fault	Year	Fault Displacement (feet)	Earthquake Magnitude (Richter)
1.	San Andreas	1906	20	8.3
2.	Imperial	1940	19	7.1
3.	Manix	1947	0.25	6.4
4.	Imperial	1966	0.05	3.6
5.	San Andreas	1966	0.6	5.5

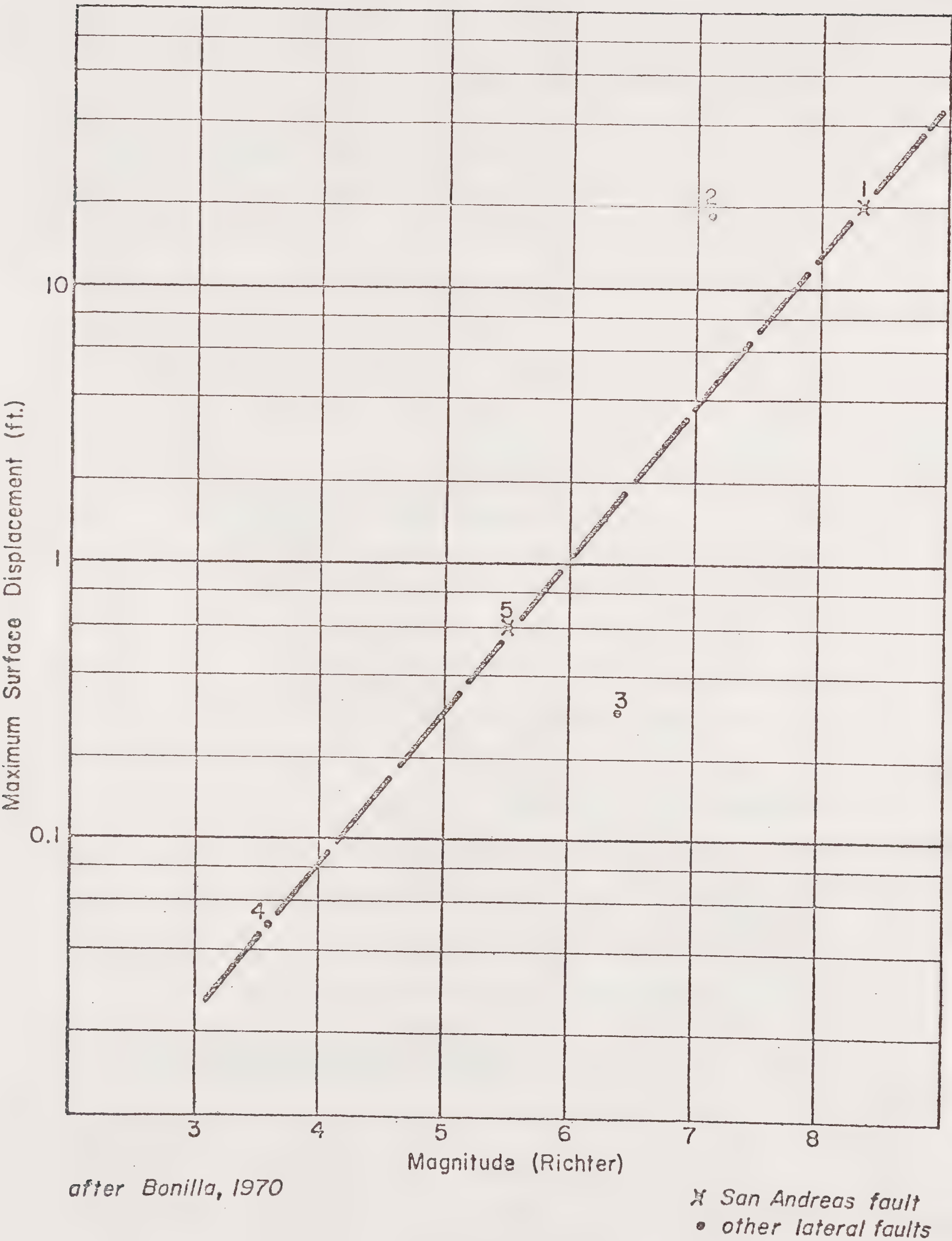


Figure 9. Earthquake magnitude vs. surface displacement for strike-slip faults. Data from Bonilla, 1970.

Magnitude and displacement (Figure 9) can be combined with a rate of displacement from survey information to give recurrence intervals for various magnitudes. Figure 10 shows this relationship for the approximate rate of displacement of a 6 cm/year. The most important consideration is that 69 years have passed since this segment last moved. If the 6 cm/year rate is valid, the energy stored already is sufficient to generate an earthquake of a magnitude of approximately 8.1. The estimated magnitude of the great San Francisco earthquake of 1906 was 8.3.

The reasoning developed in the paragraphs above is not new to most geologists, seismologists and earthquake engineers. It is the reason one hears from time-to-time about the prediction of a "great earthquake" on the San Andreas fault near San Francisco.

For purposes of further analysis in later sections of this report, the magnitude of the expected earthquake is taken at 8.25. No specific recurrence interval is required for risk evaluation, as the event appears likely to occur sometime within the next 100-year period.

b. Hayward Fault

The Hayward fault has demonstrated its capacity to generate large earthquakes twice in the past 140 years. For planning considerations, it should be assumed to have a recurrence interval for larger earthquakes (approximately magnitude 7.0) about equal to that for the San Andreas fault zone, or one magnitude 7.0 earthquake every 70-100 years.

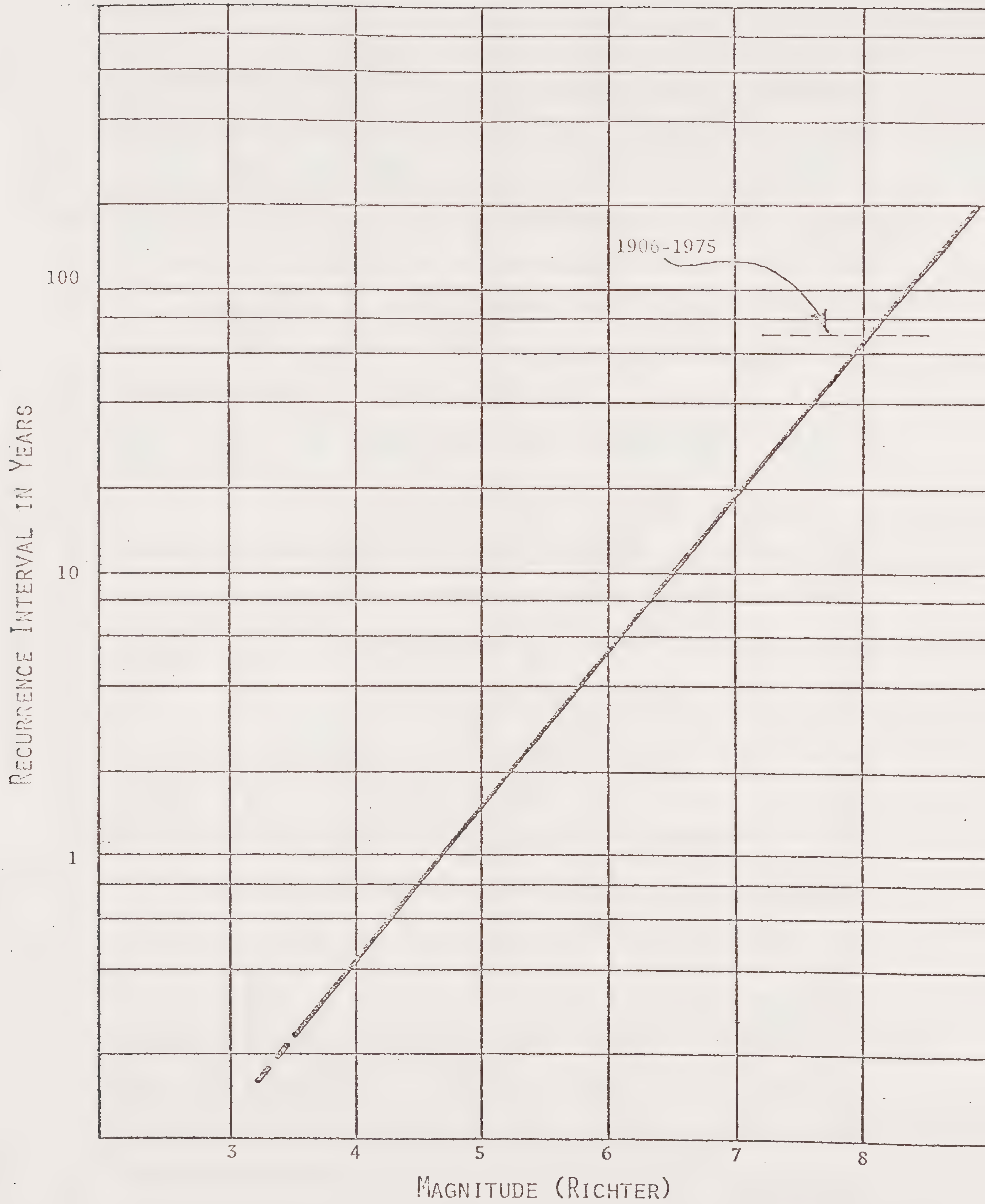


Figure 10 . Recurrence vs. magnitude for the San Andreas fault (1906 break) based on a strain accumulation of 6 cm/yr.

Surface rupturing is not expected in conjunction with earthquakes of magnitude less than 7.0. This fact is important because the energy of the smaller earthquakes will be released at some depth below the surface, and the effects at the surface will be less than for the "great" earthquake expected on the San Andreas fault. However, for an earthquake with a magnitude of over 7.0 energy will probably be released at the surface and its effects in Alameda could exceed the effects of the San Andreas fault.

c. Risk Appraisal

The analysis of events to be considered from the San Andreas and Hayward fault zones has defined these events in terms of their magnitudes and the corresponding recurrence intervals. The level of risk associated with each event is indicated by its recurrence interval in much the same manner as the risk from flooding is defined by a recurrence interval. For example, it is common practice to design flood prevention works to accommodate the flows from a 100-year storm. Where higher level of protection is desired, the design levels are increased to accommodate the flows from storms occurring at roughly 300-500 year intervals.

The risk of earthquake should be considered in a similar manner. Design for the 100-year event is considered minimum; where a higher level of protection is desired, such as for hospitals,

design levels should be increased to protect against earthquakes with longer recurrence intervals.

The City of Alameda, at a public work session on September 15, 1975, decided upon the following levels of Acceptable Risk from earthquakes expected from the San Andreas and Hayward fault zones.

Use	Recurrence Interval	Expected Magnitude	Source
Non-Critical Facilities	100 years	8.5	San Andreas
Critical Facilities	70-100 years	7.0	Hayward

Critical Facilities were divided into those which are vital to community functioning, and must remain operating at peak efficiency during and after an earthquake; and facilities which, while not vital to community functioning, must not collapse because of high levels of occupancy.

C. SURFACE RUPTURE DUE TO FAULT MOVEMENT

A study of available geological data indicates that no active or potentially active faults are known to traverse the City of Alameda. Therefore, surface rupture within the City due to movement along a fault is not considered a hazard within Alameda.

III. ENGINEERING CHARACTERISTICS OF EXPECTED EARTHQUAKES

A. METHODOLOGY

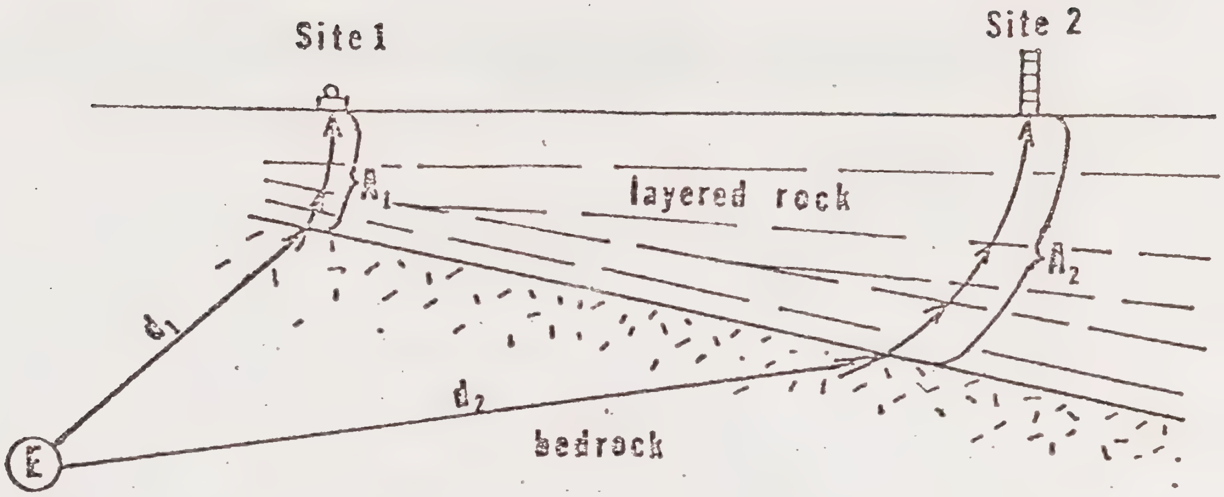
The derivation of the engineering characteristics of a particular earthquake at a particular site is normally a two-step process. These steps are the distance to the source of the earthquake, and local conditions. Where the distance factor is treated as the travel path in deep bedrock, the effect of local conditions is the near-surface amplification of the waves as they travel upward through layered rocks. The mathematics and geometry of the calculation are shown in Figure 11. The distance problem is a relatively simple part of the calculation. However, near-surface amplification and the choice of type earthquakes are more complex problems to be discussed in detail in the next two sections.

B. NEAR-SURFACE AMPLIFICATION

1. Physical Principles

The amplification of earthquake waves traveling through a media of differing physical characteristics (i.e. layered rocks) is based on two physical principles: conservation of energy, and the selective amplification of resonant frequencies.

The principle of conservation of energy applies to the transformation of the physical properties of a wave as it travels from the very fast, dense rocks at depth to the much slower, less dense rocks or soils at the surface. In this conversion,



The spectrum, S_{V1}, of the earthquake, E, recorded at site 1, at distance d_1 from the source of the earthquake is:

$$S_{V1} = \frac{E\,A_1}{d_1}$$

where A is the near-surface amplification of the bedrock motion, damping in bedrock is negligible, and spreading is cylindrical. Likewise, the spectrum at site 2 is:

$$S_{V2} = \frac{E\,A_2}{d_2}$$

Therefore:

$$S_{V2} = S_{V1}\,\frac{d_1}{d_2}\,\frac{A_2}{A_1}$$

Where S_{V1}, S_{V2}, A_1, and A_2 are complex functions of frequency.

Figure 11. Geometry and mathematics of computation of the engineering characteristics of an earthquake.

the energy wave velocity is converted to energy of wave amplitude. The mathematical expression for this change as a wave travels from layer 2 to layer 1 is:

$$AR = \frac{D_2 V_2}{D_1 V_1}$$

where: AR = amplification ratio (layer 2 to layer 1),

D_1 = density of layer 1,

D_2 = density of layer 2,

V_1 = velocity of layer 1, and

V_2 = velocity of layer 2.

The above equation involves both velocity and density, but velocity is by far the most important. In the overall change from granite at a depth to an average soil at the surface, the density will typically change from 2.7 to about 1.5; a ratio of less than 2:1. Velocity (shear-wave), on the other hand, will typically change from about 11,000 ft/sec to less than 500 ft/sec; a ratio of more than 20:1, and 10 times the density change.

The <u>selective amplification of resonant frequencies</u> is more complex, but in simple terms, the rock layers act somewhat like a series of organ pipes that amplify waves of particular frequencies. The frequencies that are amplified are those that form a one-quarter-wavelength standing wave in the layer, and all higher modes. The dominant periods of a layer are thus:

$$T = \frac{4H}{1V}, \frac{4H}{3V}, \frac{4H}{5V}, \text{ etc.}$$

where: T = dominant period,

H = layer thickness, and

V = layer velocity (shear wave).

For most sites, with many layers of varying thickness and a gradual increase of velocity with depth, selective amplification is secondary in importance to the more general amplification due to decreasing velocity and density. However, where there is a very pronounced velocity change at relatively shallow depth, as in the Mexico City area discussed in the Introduction, the concentration of energy in a narrow frequency range can be very important for structures having a similar natural period of vibration.

In addition to the two principles considered above, damping can be important for sites with thick layered sequences. Waves traveling in fast, dense rocks such as granite, are almost unaffected by damping, but unconsolidated materials such as soils, soft sands and shales can effectively damp earthquake waves if they are present in sufficient thickness. Overall, the effect is to cancel a part of the wave amplification of the slow, less dense rocks, because rocks with high amplification characteristics generally have high damping factors. For damping to be effective, however, thick layers are required. Thus, low velocity materials may be "good" or "bad". If they are present as a relatively thin layer (15-100 feet),

amplification may be very significant. However, if they are present as very thick layers (several thousands of feet), damping can be effective in reducing the amplification normally expected at sites underlain by low velocity rocks.

From the discussion above, it is apparent that the most important physical characteristics of a site is the velocity or velocities of the layers underlying the site. Density is less important, and it can be estimated from velocity if the rock types are known. Damping is important for thick sections, and it, too, is closely related to velocity. Thus, if the velocity of the wave type of interest is known, the density and damping can generally be estimated to an acceptable degree of accuracy.

Earthquake shaking is the result of complex combinations of several types of vibrational waves. The primary components of earthquake waves are the so-called body waves that travel through the deeper parts of the earth's crust. Body waves include the primary (P-wave) or compressional waves and the secondary (S-wave) or shear waves. For waves traveling at depth, and refracted upward to the site (Figure 11), the P-waves, vibrating parallel to the propagation direction, dominate the vertical component of shaking. The S-waves arrive later and vibrate normal to the direction of propagation; they make up the major part of the damage-inducing, horizontal components of shaking. Thus, it is the shear waves that are of primary importance in the analysis of earthquake shaking.

C. MODEL ANALYSIS

The analysis of near-surface amplification by various combinations of geologic conditions in the area is based on a series of computer-generated amplification spectra based on models of subsurface conditions. These conditions vary significantly within the area and considerable generalization is necessary if the results are to be applied to a workable microzonation system.

To determine the amplification characteristics of the various bedrock/soil combinations in Alameda, detailed geophysical models have been developed for typical sites within the study area. These models (Tables 4 through 6) represent a combination of published and unpublished geological and geophysical data (P-wave, velocity, density) and soil parameters from soil engineering reports submitted to the City. Where geophysical data was lacking, such as for the velocities of deeper layers, approximations have been made using information from areas with similar characteristics included in Duke and Leeds (1962) and Duke, et al (1971).

A computer analysis of the above models yields the amplification spectra for each of the typical bedrock/soil combinations in the study area. These spectra are presented as Figures 12 through 14. A study of the amplification characteristics of the sites indicates that in general, the amplification spectra can be grouped into two categories as follows:

TABLE 4

SITE: Bay Mud 1

Location: Alameda

Top of Unit	Geology	S-Wave Velocity	Thickness	Density	Damping
0	Young Bay Mud	300	15	50	0.02
15		700	20	60	0.02
35	Merritt Sand	1000	50	105	0.02
85	Pleistocene Sediments	1200	100	110	0.02
185		1500	100	110	0.02
285		2000	100	110	0.02
385	Weathered Franciscan	6000	100	150	.00625
485	Basement Complex	11000	10000	165	.00385

Footnotes:

1) Warrick, R.E., 1974; Duke and Leeds, 1962; Duke et al, 1971
2) Goldman, H.G., 1969; Blake, et al, 1974
3) Lee, C.H., and Praszker, M., 1969; Goldman, H.D., 1969; Woodward-Lundgren & Associates, May and December, 1974; Duke, et al, 1971
4) Duke, et al, 1971

TABLE 5

SITE: Bay Mud 2 LOCATION: Alameda

Top of Unit	Geology	S-Wave Velocity	Thickness	Density	Damping
0	Young Bay Mud	300	15	50	0.02
15		700	60	60	0.02
75	Merritt Sand	1000	50	105	0.02
125	Pleistocene Sediments	1200	100	110	0.02
225		1500	100	110	0.02
325		2000	100	110	0.02
425	Weathered Franciscan	6000	100	150	.00625
525	Basement Complex	11000	10000	165	.00385

Footnotes:

1) Duke and Leeds, 1962; Duke, et al, 1971
2) Goldman, H.B., 1969; Blake, et al, 1974
3) Woodward-Lundgren and Assoc., May and December, 1974; Duke, et al, 1971
4) Duke et al, 1971

TABLE 6

SITE: MERRITT SAND

LOCATION: ALAMEDA

Top of Unit	Geology	S-Wave Velocity	Thickness	Density	Damping
0	Merritt Sand	675	25	105	0.02
25		1150	25	110	0.02
50	Pleistocene Sediments	1200	100	110	0.02
150		1500	100	110	0.02
250		2000	100	110	0.02
350		2250	100	115	0.02
450	Weathered Franciscan	6000	100	150	.00625
550	Basement Complex	11000	10000	165	.00385

Footnotes:

1) Duke and Leeds, 1962; Duke, et al, 1971
2) Goldman, H.B., 1969; Blake, et al, 1974
3) Woodward-Lundgren and Assoc., May and December, 1974; Duke, et al, 1971
4) Duke et al, 1971

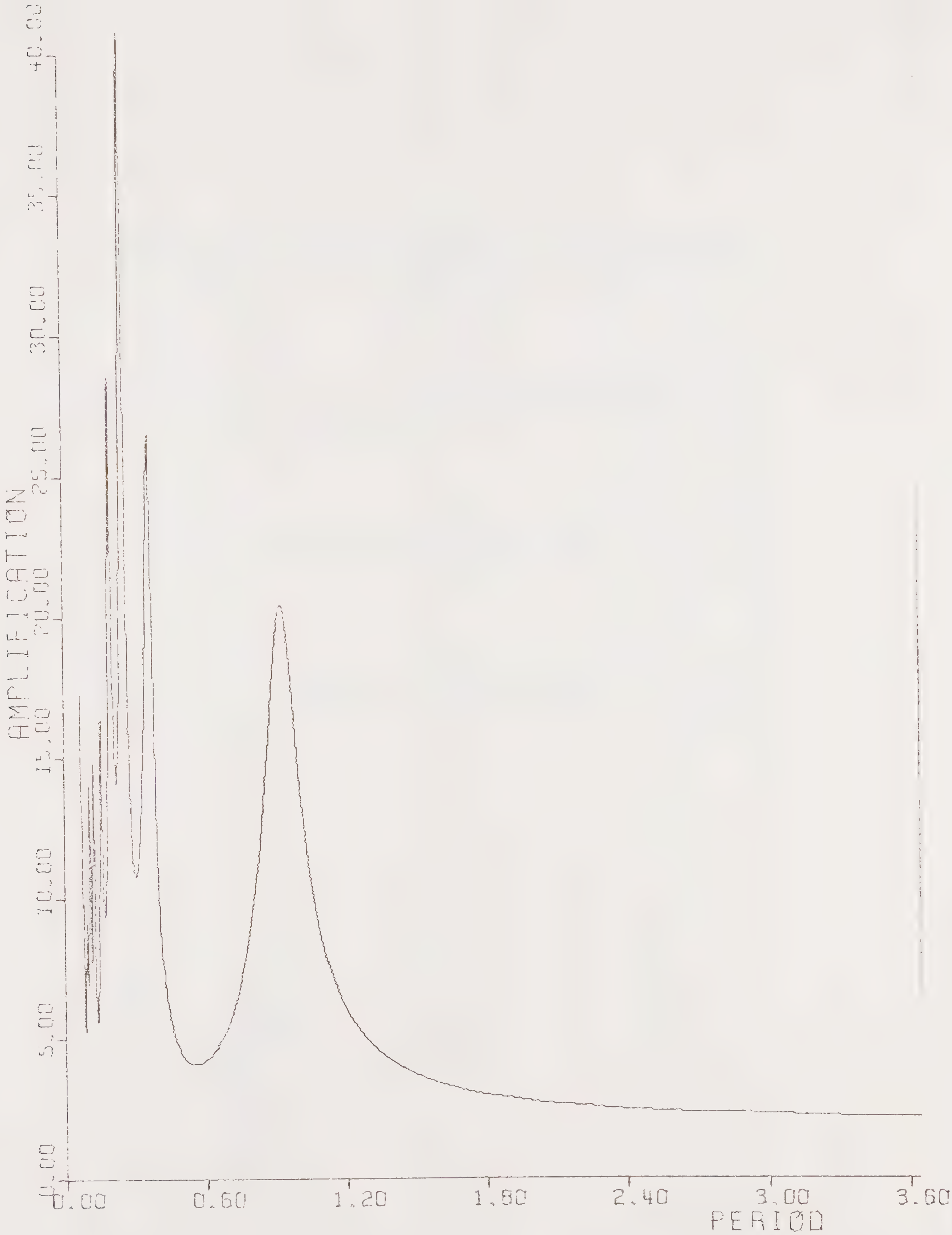


Figure 12. Amplification spectrum for sites underlain by 35 feet of Bay Mud.

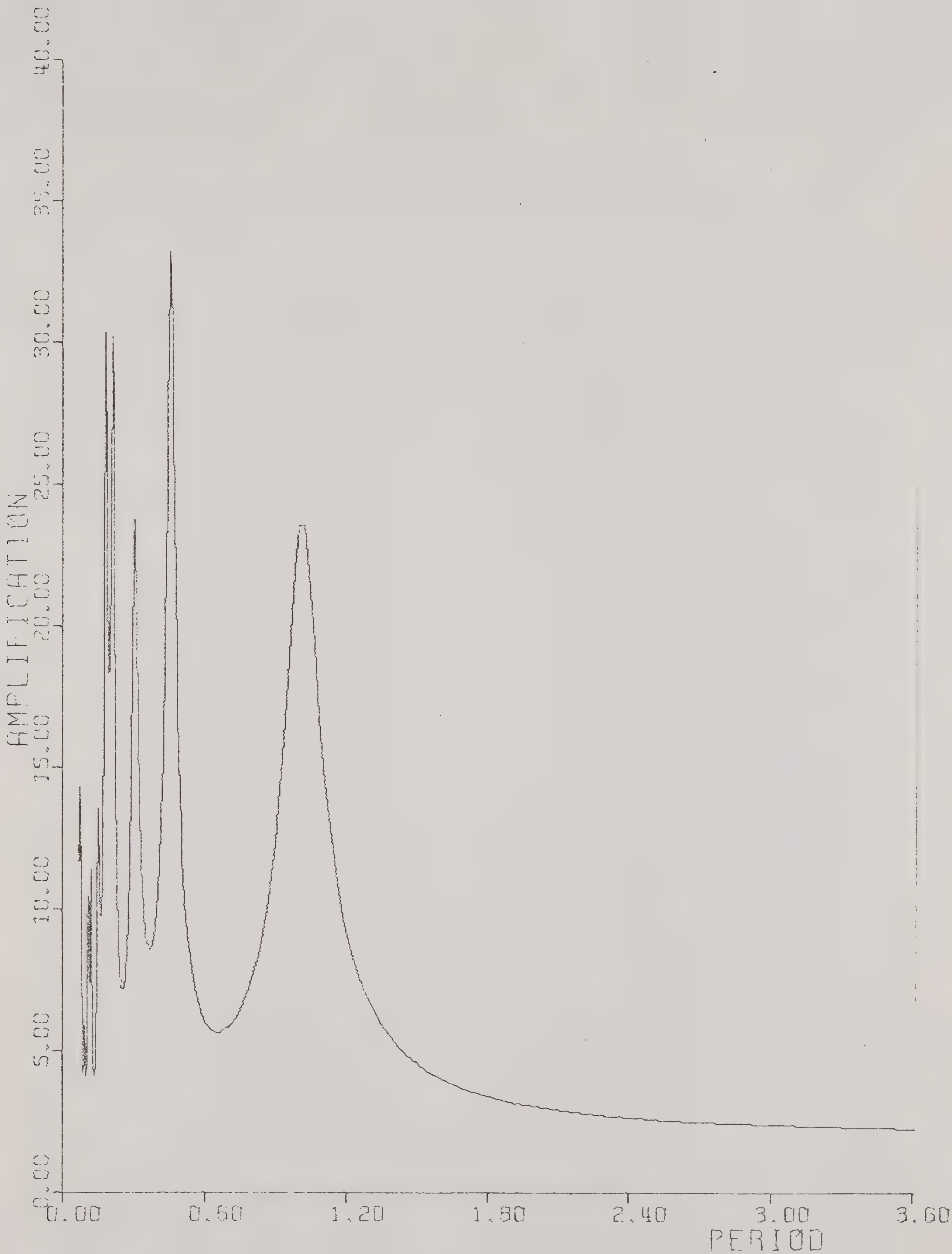


Figure 13. Amplification spectrum for sites underlain by 75 feet of Bay Mud.

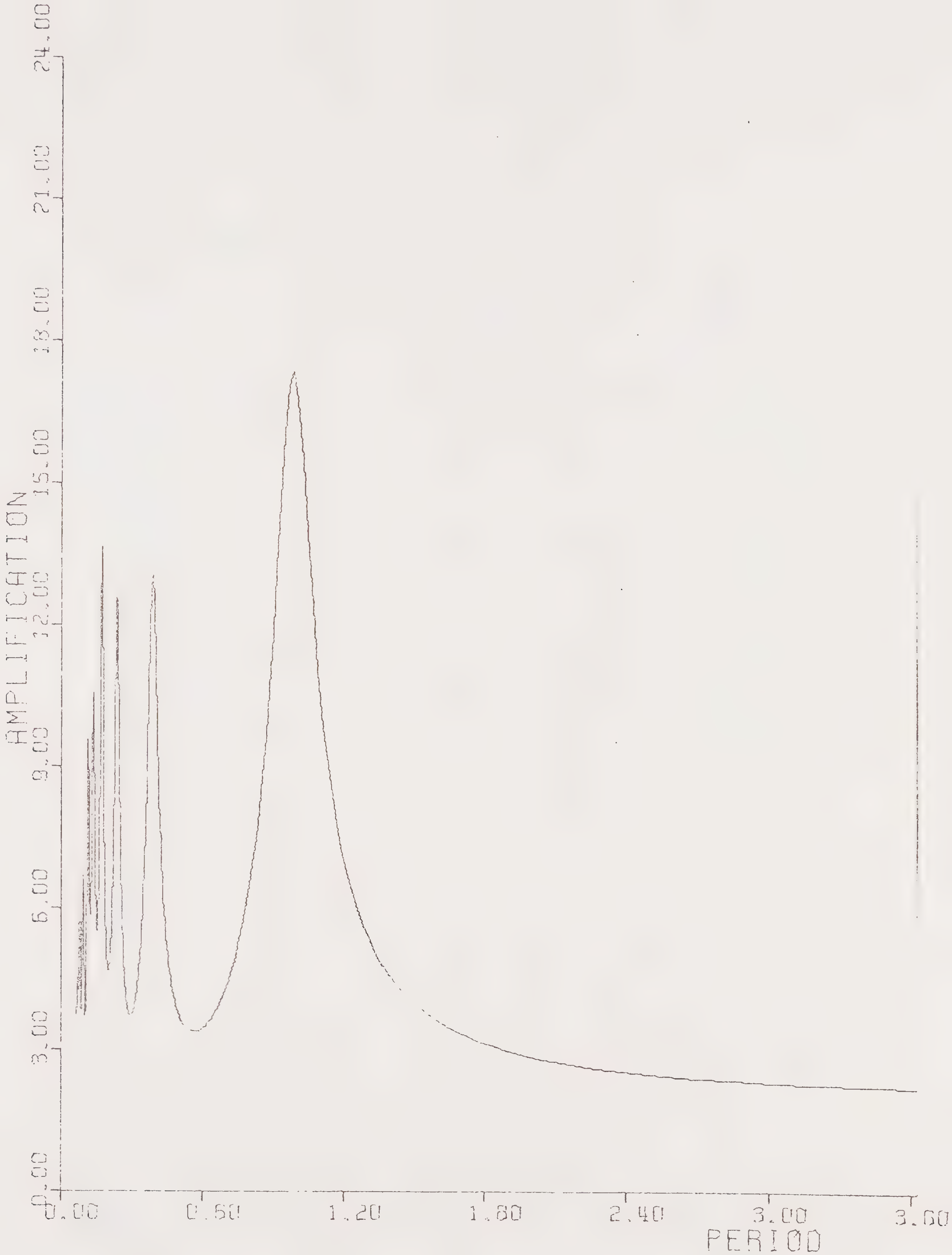


Figure 14. Amplification spectrum for sites underlain by Merritt Sand.

1. Figures 12 and 13 - Representative of areas underlain by Bay Mud.
2. Figure 14 - Representative of areas underlain by Merritt Sand.

The smoothed amplification spectra resulting from the above combinations are presented as Figures 15 and 16. It is these spectra that will be used in the ensuing groundshaking analysis. Some mention should be made here of the "trough" in the amplification spectra for the Bay Mud sites (Figures 12 and 13) in the period range between about 0.5-0.8 seconds and the apparent disregard for this "trough" on Figure 15. Figures 12 and 13 represent two typical thicknesses of Bay Mud; one of 35 feet thick and the other 75 feet thick. Since the Bay Mud is known to range from 0-100 feet thick in the study area, and the "trough" shifts position with varying thickness, Figure 15 represents the probable envelope of amplification spectra for all thicknesses of Bay Mud. It is important to note that the effects of site conditions vary continuously in the natural environment. However, a workable system requires establishing specific categories of conditions within which a "typical" or "average" condition can be considered as representative of that category.

Artificial fills are present around the perimeter of the island. These fills vary considerably in engineering properties, thickness, and age. It is our opinion, based on Seed (1969), that the expected ground shaking parameters, irrespective of secondary ground failure, can be assumed to be similar to that of the Bay Mud.

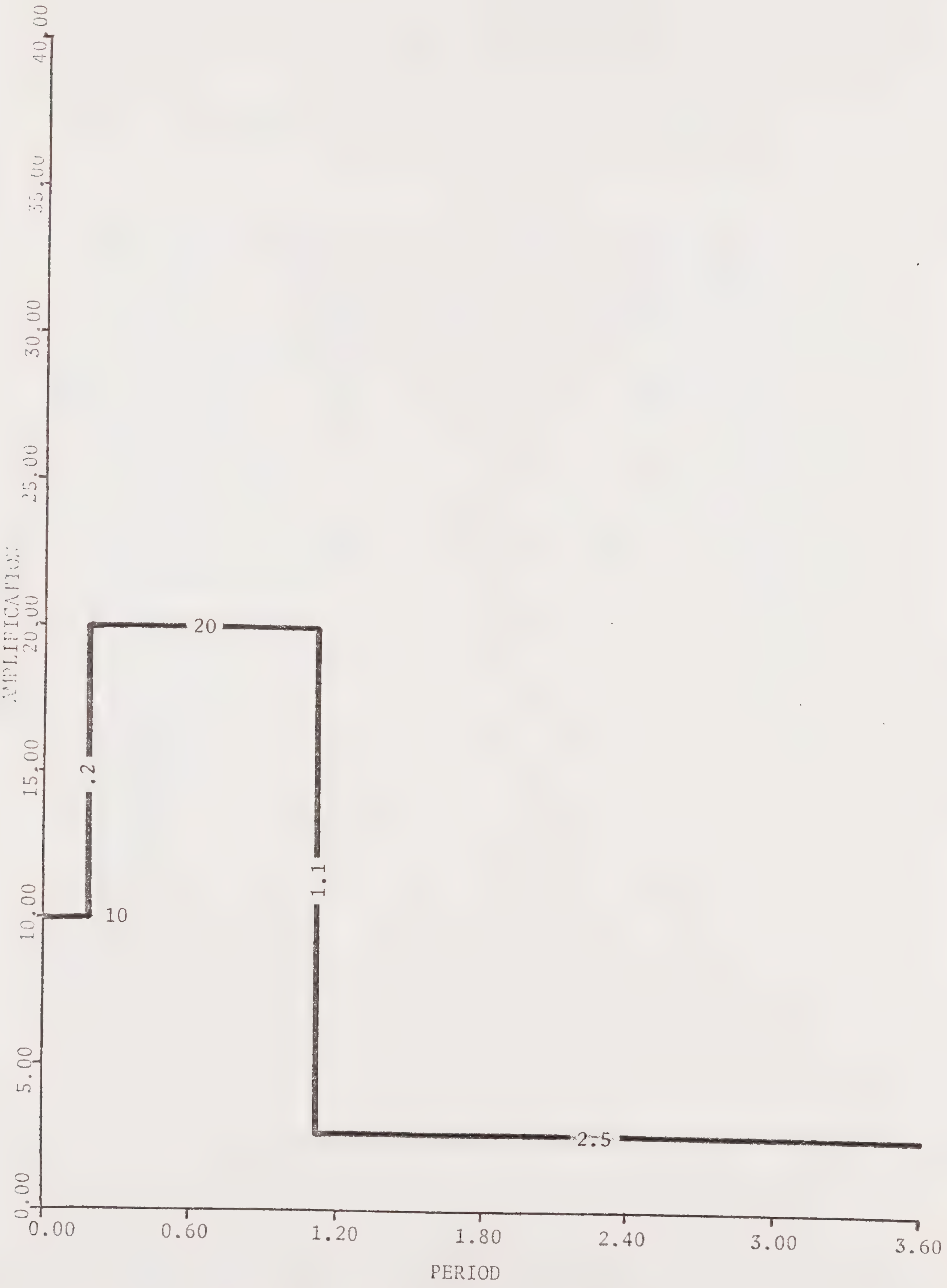


Figure 15. Smoothed amplification spectrum for sites underlain by Bay Mud.

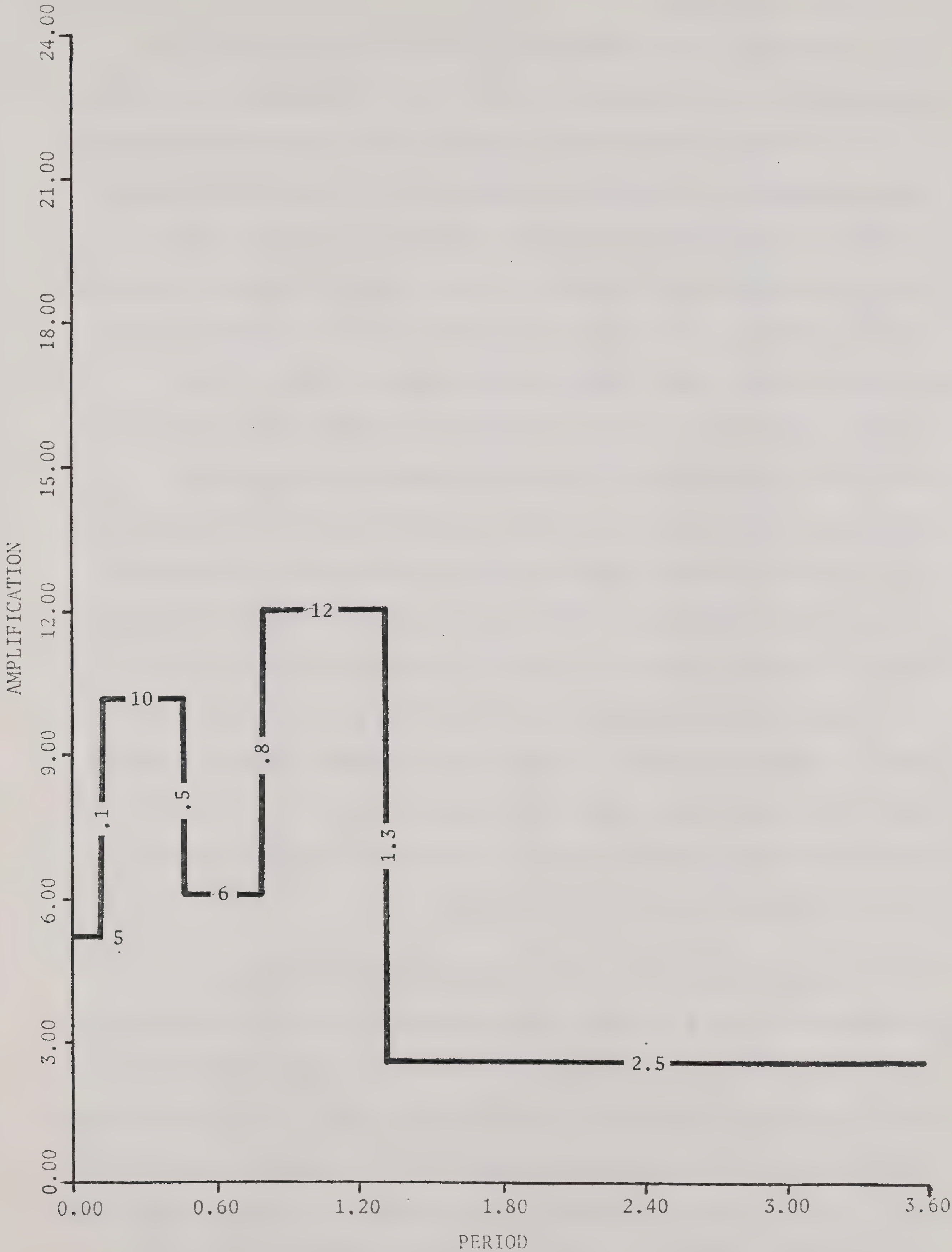


Figure 16. Smoothed amplification spectrum for sites underlain by Merritt Sand.

D. TYPE EARTHQUAKES

Type earthquake, as used herein, is the strong motion of earthquake E, as recorded at Site 1 as illustrated on Figure 11. The strong motion to be used in computing the engineering characteristics of expected shaking for critical facilities is the two horizontal components of motion of the 1940 El Centro earthquake as recorded at the Imperial Valley Irrigation District Office in El Centro 4 miles from the surface trace of the slipped fault (Trifunac and Brune, 1970). The Richter magnitude of this earthquake has been most recently set at 6.3 (Earthquake Engineering Research Laboratory, 1971), and the surface movement was dominantly horizontal. It is considered the best available analogy to earthquakes of about this magnitude that may be expected on the Hayward Fault. The acceleration, velocity and displacement of the two horizontal components of motion of this earthquake are shown on Figures 17 and 18, and the response spectra derived from the records are shown on Figures 19 and 20. The smoothed envelope of the spectra used in computing the spectra for the study area is shown on Figure 20.

The strong motion of an earthquake comparable to the magnitude 8.0 to 8.5 earthquake expected from the San Andreas fault has not been recorded. To fill this gap, the motion has been simulated by Jennings, Housner and Tsai (1968) and by Seed and Idriss (1969) using the records of the larger earthquake (e.g. Taft record of the Arvin-Techachapi earthquake) and theory regarding the variation in earthquake characteristics with

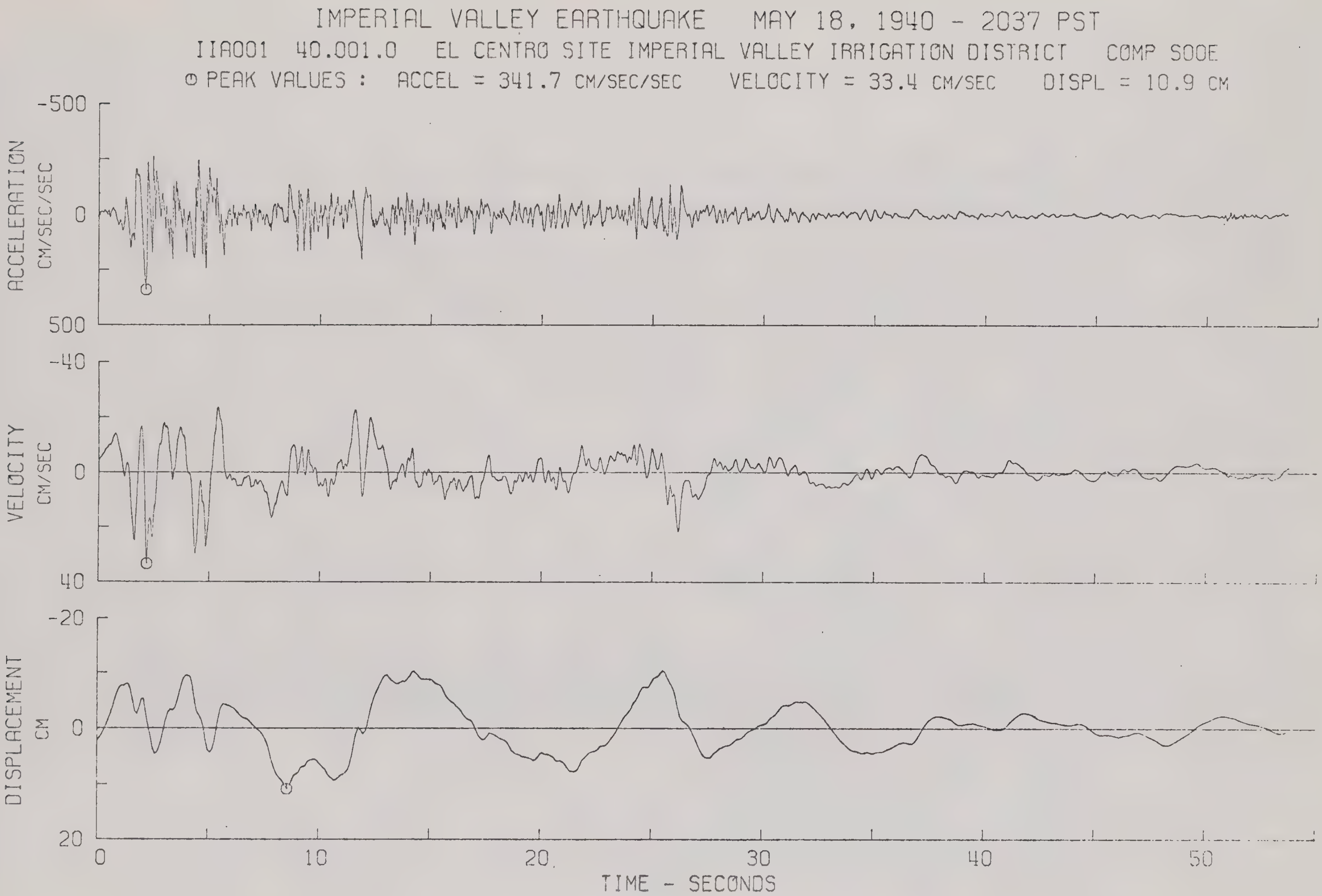


Figure 17. Acceleration, velocity and displacement for the north-south component of ground motion of the 1940 Imperial Valley earthquake.

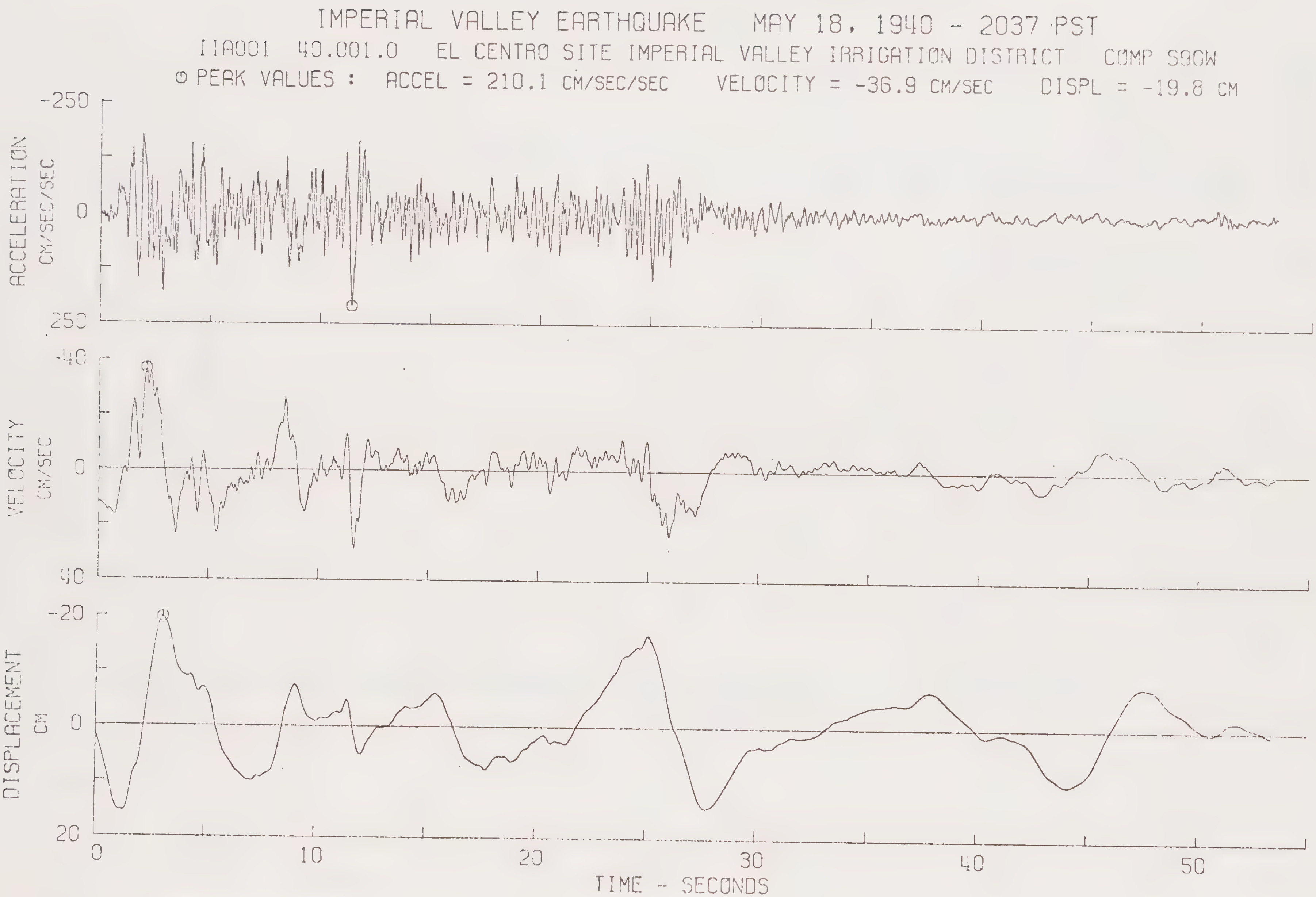


Figure 18. Acceleration, velocity and displacement for the east-west component of ground motion for the 1940 Imperial Valley earthquake.

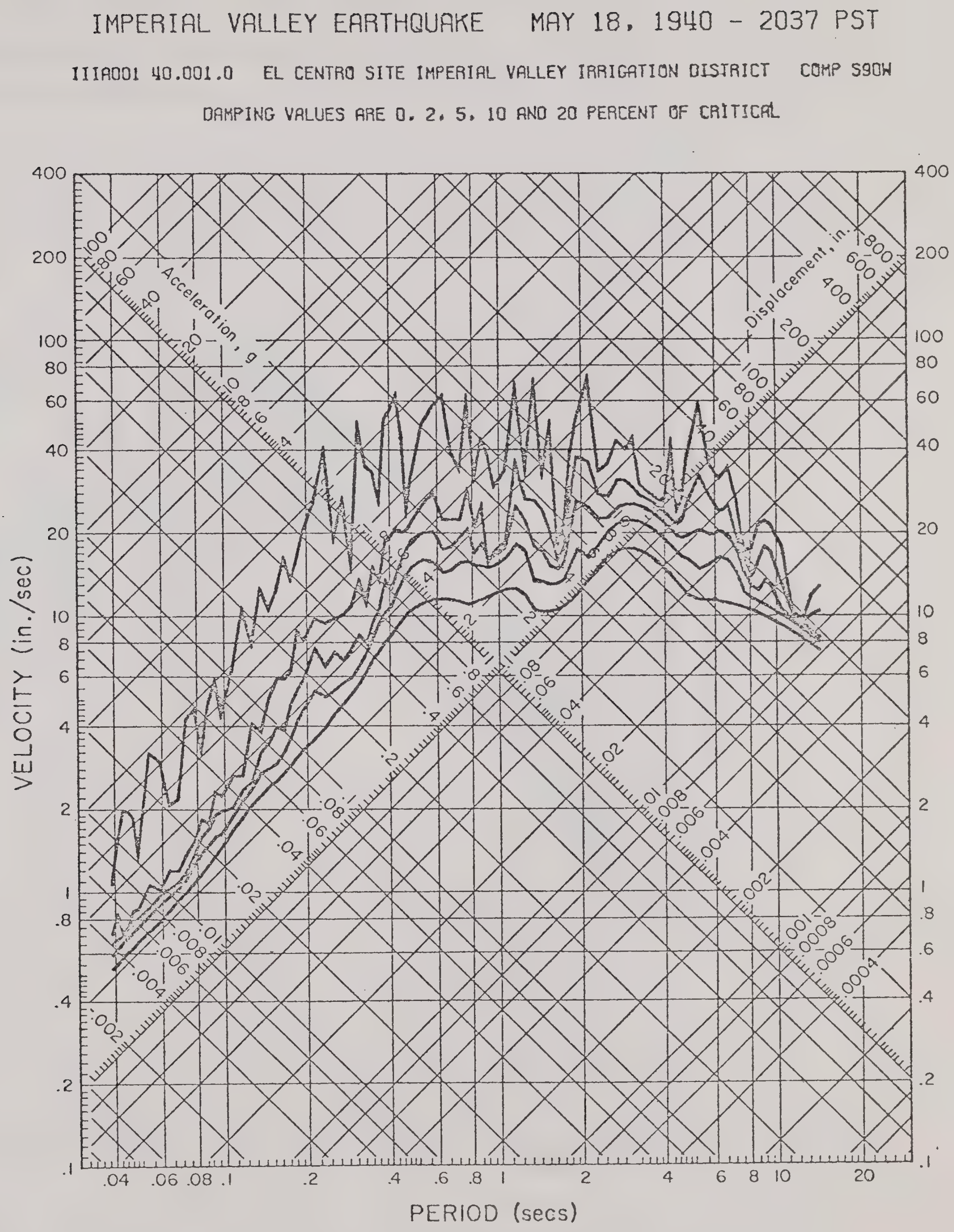


Figure 19. Response spectrum of east-west component of ground motion of the 1940 Imperial Valley earthquake (Figure 17).

IMPERIAL VALLEY EARTHQUAKE MAY 18, 1940 - 2037 PST

IIIA001 40.001.0 EL CENTRO SITE IMPERIAL VALLEY IRRIGATION DISTRICT COMP S00E

DAMPING VALUES ARE 0, 2, 5, 10 AND 20 PERCENT OF CRITICAL

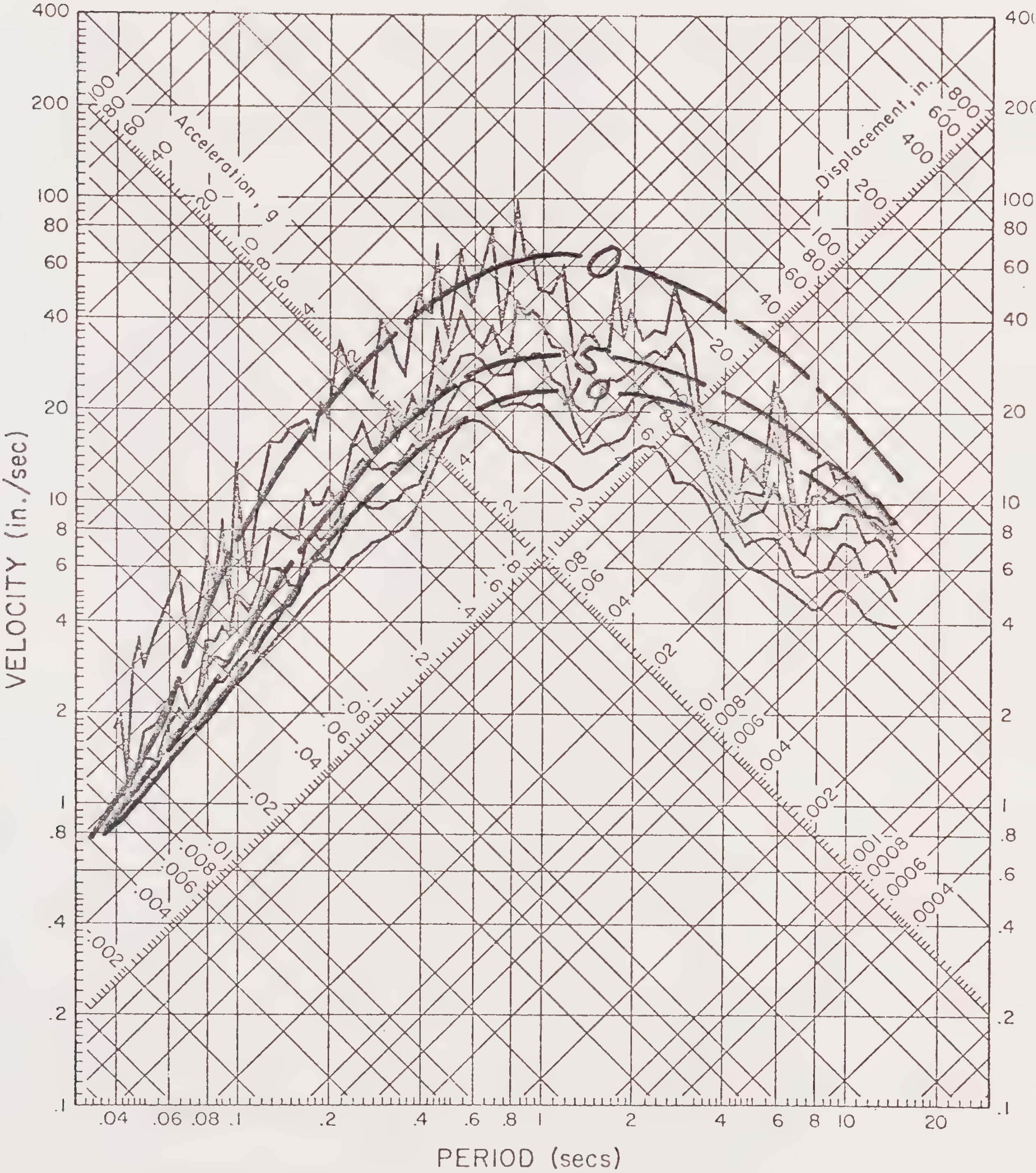


Figure 20. Response spectrum of the north-south component of ground motion of the 1940 Imperial Valley earthquake (Figure 18) with smoothed envelopes (dashed lines) of curves for both components.

increasing magnitude. The results of the two studies are very similar. The response spectra of the two simulated motions agree well up to a period of about 2.0 seconds, but for the longer periods the motion proposed by Seed and Idriss has substantially lower response. The motion proposed by Jennings, Housner and Tsai has been used in this study because it assumes a site on alluvium which better fits the study area. The response spectra for one component of this motion is included as Figure 21. In addition to the actual response for the various damping factors, smoothed envelopes of both horizontal components (A-1 and A-2) for 0%, 5%, and 10% of critical damping have been added as dashed curves. It is these smoothed response curves that will be used as the response spectrum of the "type earthquake" in the analysis of shaking expected from the San Andreas fault.

E. MICROZONATION

As developed in the section on Methodology, earthquake shaking at a site is dependent on both distance to the fault and site geology. The mathematics of combining these factors is given in Figure 11. The terms of this equation:

$$S_{V2} = S_{V1} \frac{d_1}{d_2} \frac{A_2}{A_1}$$

state that the response spectrum at the site in question, S_{V2}, is derived by multiplying the response spectrum of the recorded earthquake motion, S_{V1}, by the inverse ration of the distances to the fault that is the source of the recorded earthquake

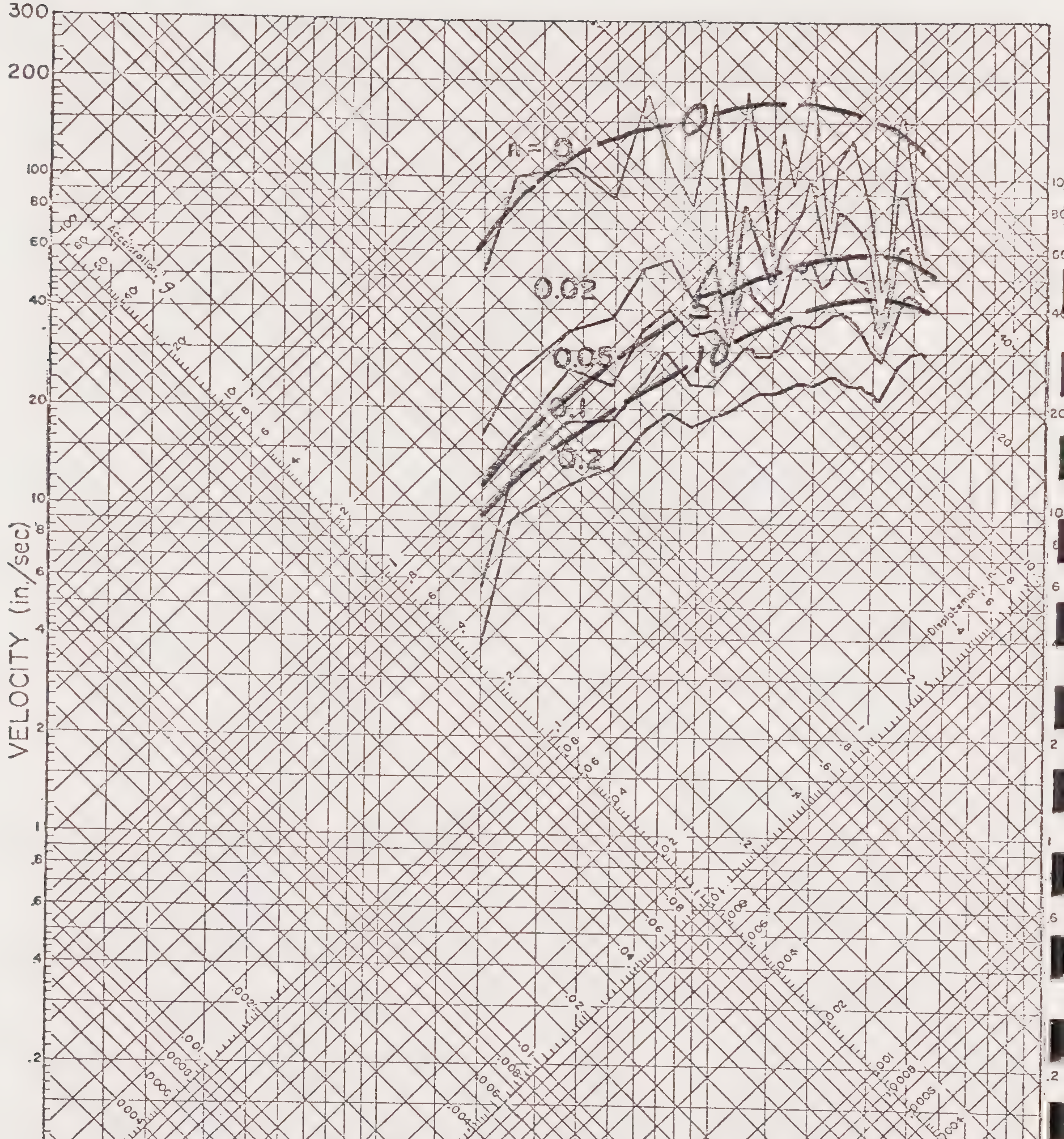


Figure 21. Response spectrum for simulated earthquake A-1 of Jennings, Housner & Tsai, 1968. Dashed curves are smoothed envelopes of A-1 and A-2 spectra for 0, 5, and 10% of critical damping.

d_1/d_2, and the ratio of the near-surface amplification spectra, A_2/A_1. As developed in the preceding two sections, the response spectra and the amplification spectra are not simple numbers, but are functions of frequency (or its inverse, period). This process is shown diagrammatically in Figure 22 in terms of the data developed in the preceding sections. The response spectrum of the recorded earthquake (S_{V1}) is either Figure 21 or 22 (dashed curves), depending on which earthquake is considered. The amplification spectrum at the site of the recorded earthquake (A_1) is Figure 23, and the amplification at the "site in question" (A_2) could be either of the amplification spectra of Figures 17 or 18.

The equation discussed above is directly applicable to a specific site, and its use in zonation requires some additional explanation as to the choice of a "typical" or "average" amplification spectrum for each of the site types, and the choice of the distance boundaries used in the microzonation. The grouping of the various models of site conditions into specific site types that can be utilized in the zonation of the area requires considerable geologic judgment. Based on the results of the modeling of conditions in the Alameda area and experience in other areas, the following types of site conditions have been chosen:

Map Symbol	Site Type
M	Areas underlain by Bay Mud
S	Areas underlain by Merritt Sand

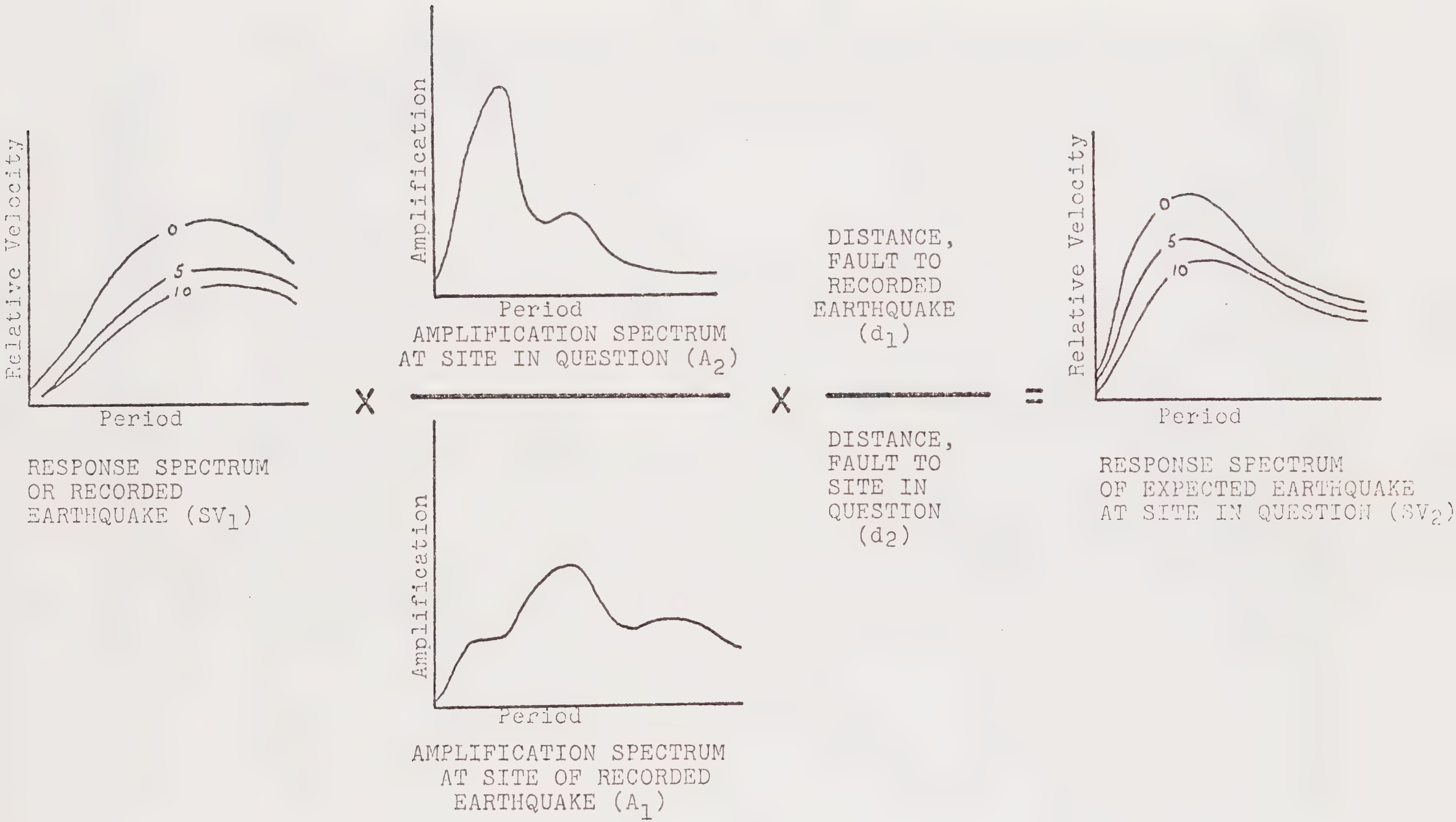


Figure 22. Diagrammatic representation of the calculation of the response spectrum of an expected earthquake.

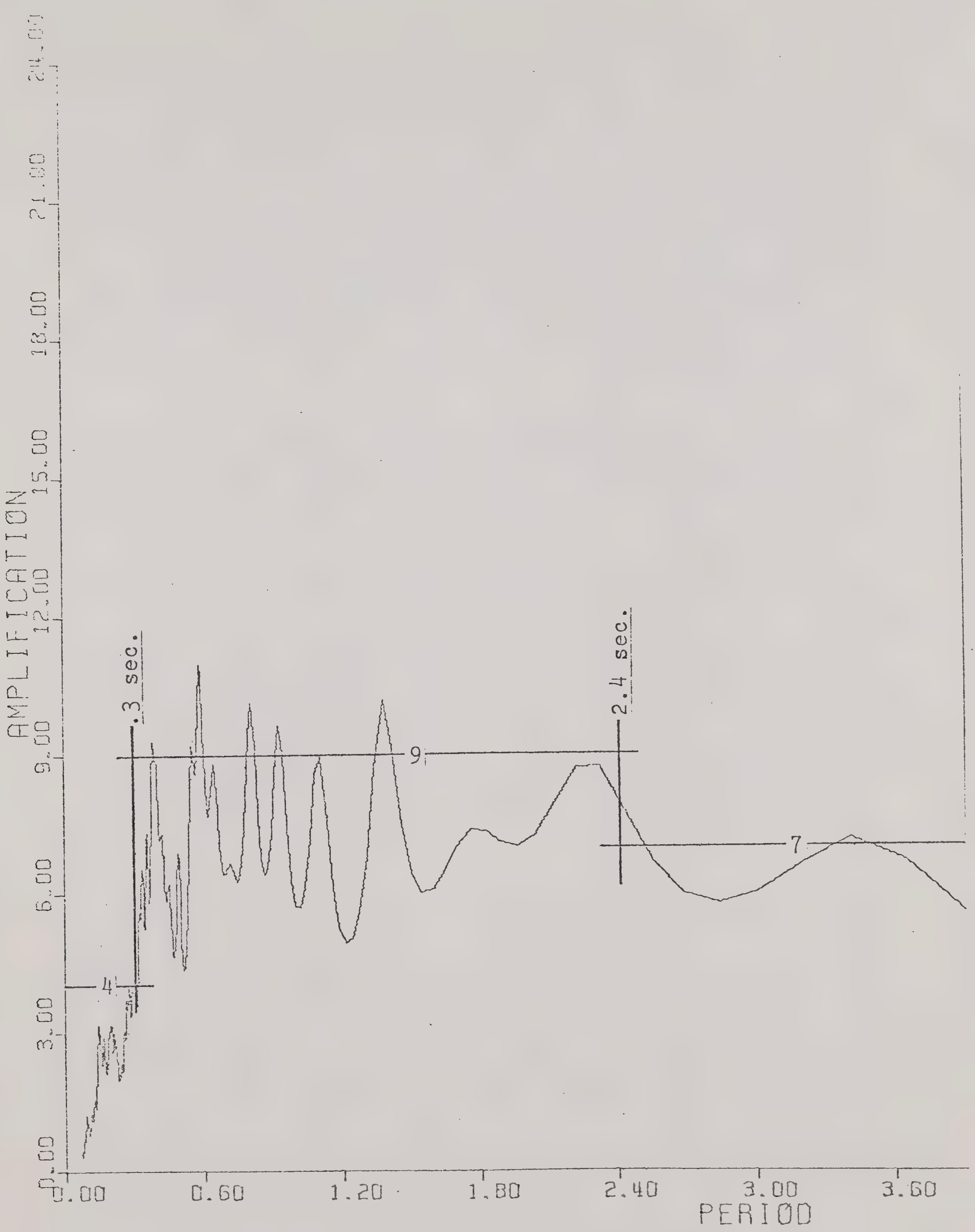


Figure 23. Amplification spectrum for El Centro accelerograph site.

The decrease of intensity due to increasing distance is, theoretically, a simple 1/d relationship, but experience indicates there are variations in this linearity, particularly for distances close to the fault. If nothing else, it is apparent that as d goes to zero, the spectral values become infinite. Since this is not an acceptable solution, some modification of the d_1/d_2 segment of the equation in Figure 22 is required.

Studies of the attenuation of maximum ground acceleration with distance by Schnabel and Seed (1973) offer a reasonable solution to this problem. Their attenuation curves for various magnitude earthquakes (Figure 24), as modified by Greensfelder (1974), are used herein to define the boundaries of the distance zones and to modify the 1/d relationship. These attenuation curves are also used to modify (scale) the spectra of the magnitude 6.3 El Centro earthquake to the spectra that would be expected had the magnitude of this earthquake been 7.0.

The general characteristics of earthquake shaking for each of the zones as discussed above are summarized in Table 7, and the spectra for the zones as referenced in the table are included as Figures 25 through 30. The areal distribution of the zones in Alameda is shown on Plate I.

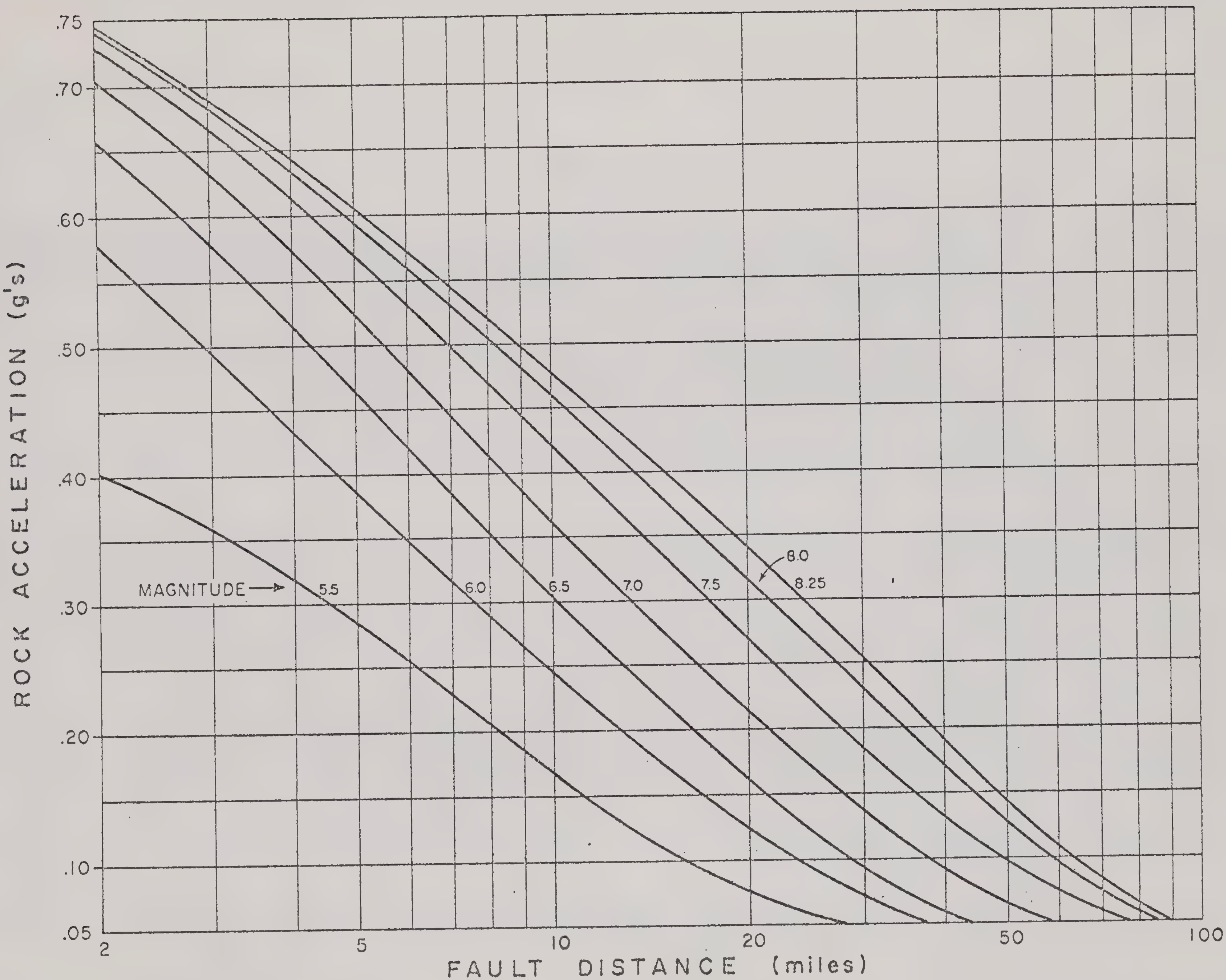


Figure 24. Attenuation of rock acceleration with distance for earthquake magnitude of 5.5 to 8.25. (From Greensfelder, 1974).

TABLE 7

GENERALIZED CHARACTERISTICS OF EXPECTED EARTHQUAKES
ALAMEDA, CALIFORNIA

	Non-Critical Facilities				Critical Facilities			
Zone	g	T	t	S	g	T	t	S
1S	0.56	0.2-0.4	40-50	25	0.67	0.2-0.3	20-30	27*
2S	0.56	0.2-0.4	40-50	25	0.56	0.2-0.3	20-30	28*
1M	1.1	0.2-0.5	50-60	26	1.3	0.2-0.4	25-35	29*
2M	1.1	0.2-0.5	50-60	26	1.1	0.2-0.4	25-35	30*

g = Maximum ground acceleration expressed as a decimal fraction of the acceleration of gravity.
T = Predominant period of ground shaking in seconds.
t = Duration of "strong" shaking in seconds.
S = Figure number for applicable response spectra.

*Consider also the response spectrum for non-critical facilities (Figures 25 or 26) as the spectral values for this event exceed those for the event nominally assigned to this use group for a part of the range of periods.

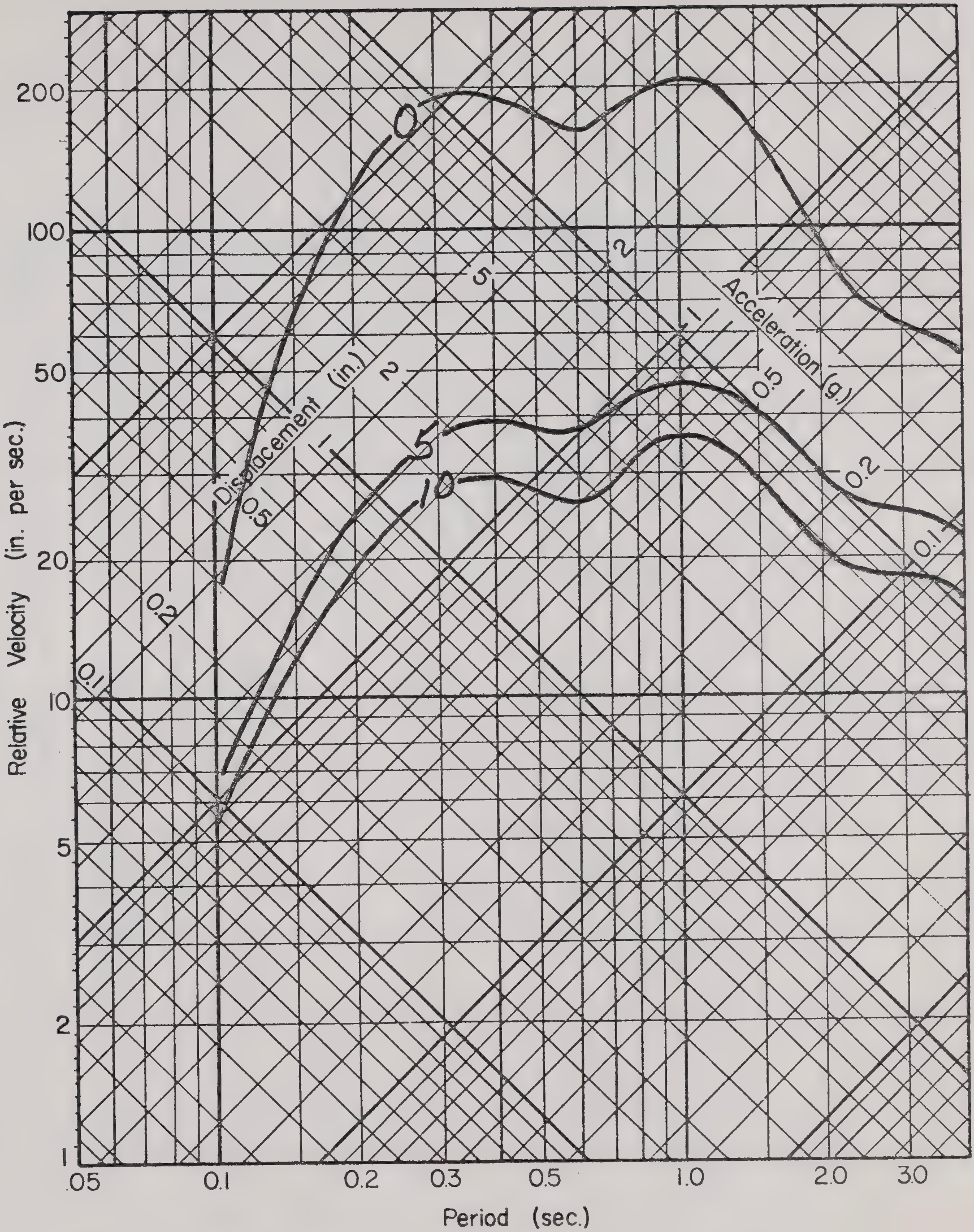


Figure 25. Response spectrum for Zones 1S and 2S of magnitude 8.25 event on San Andreas fault for 0, 5, and 10% of critical damping.

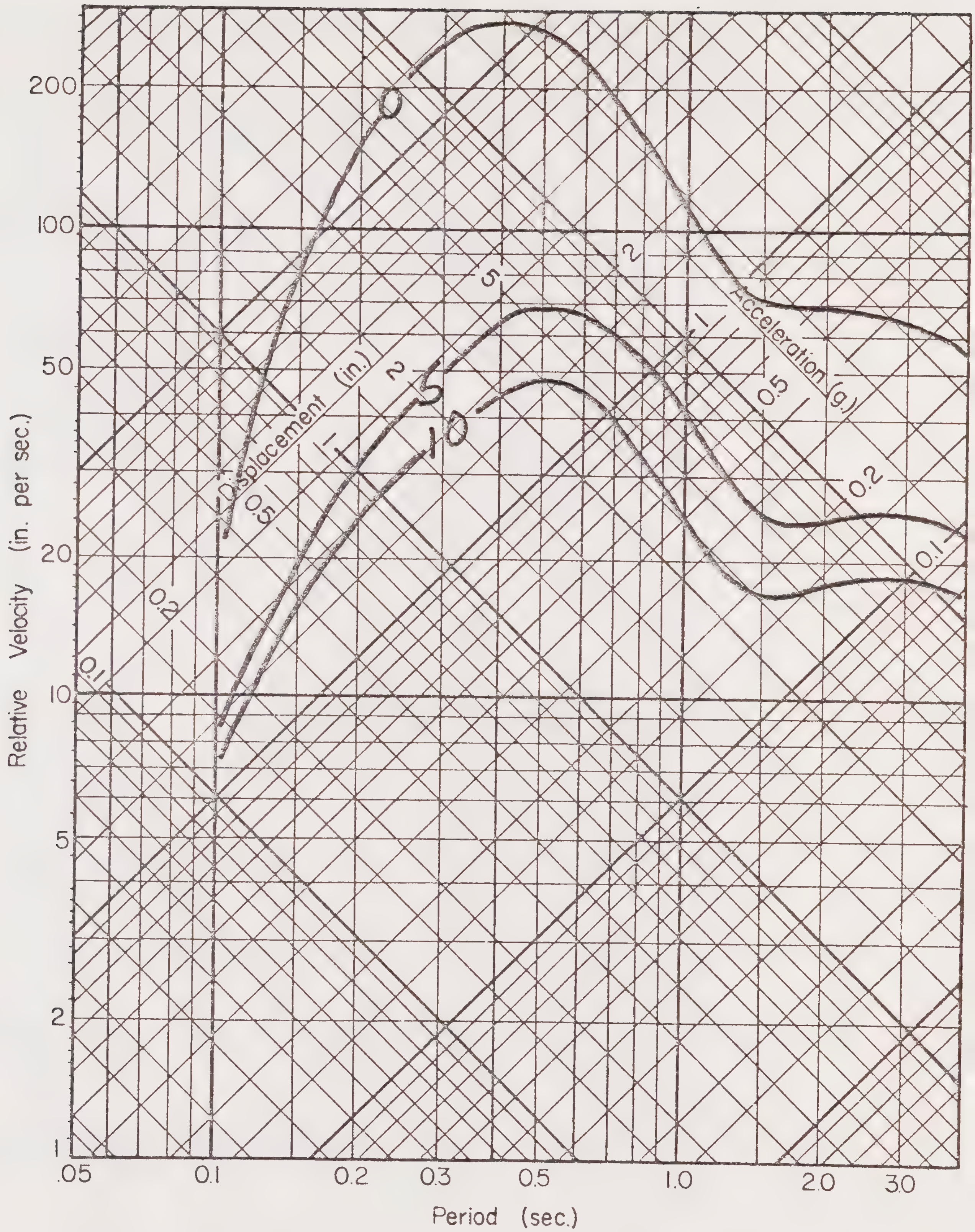


Figure 26. Response spectrum for Zones 1M and 2M of magnitude 8.25 event on San Andreas fault for 0, 5, and 10% of critical damping.

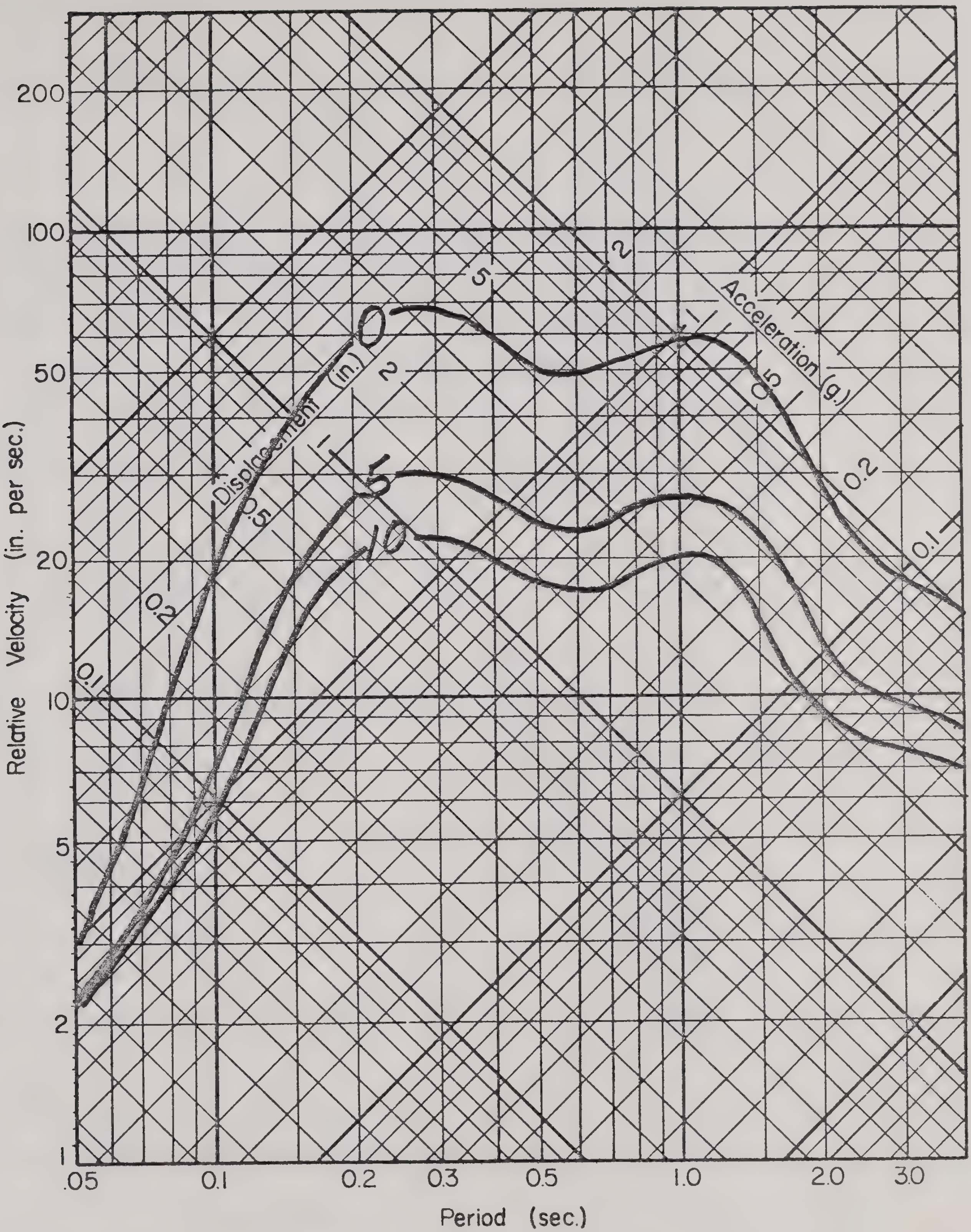


Figure 27. Response spectrum for Zone 1S of magnitude 7.0 event on Hayward fault for 0, 5, and 10% of critical damping.

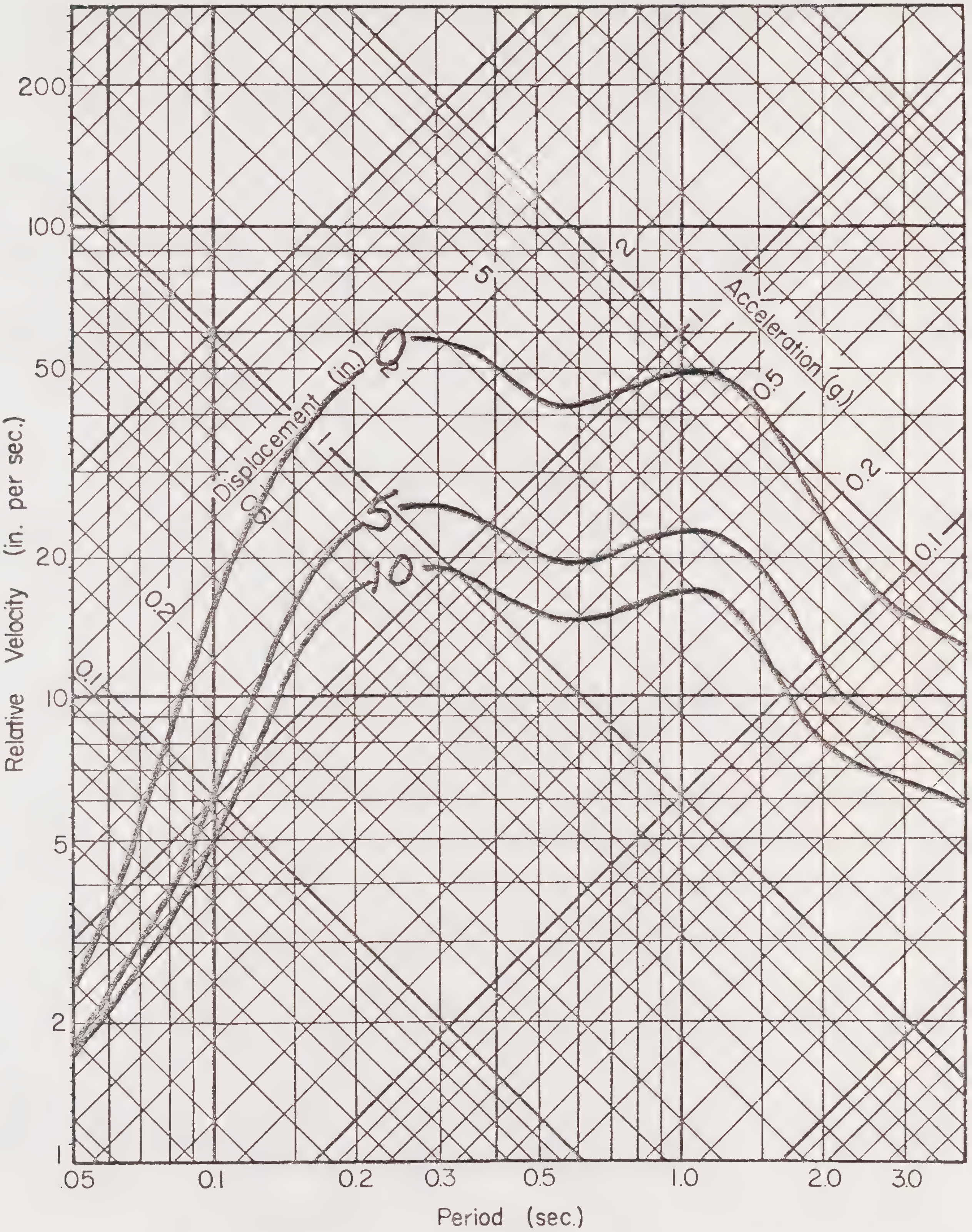


Figure 28. Response spectrum for Zone 2S of magnitude 7.0 event on Hayward fault for 0, 5, and 10% of critical damping.

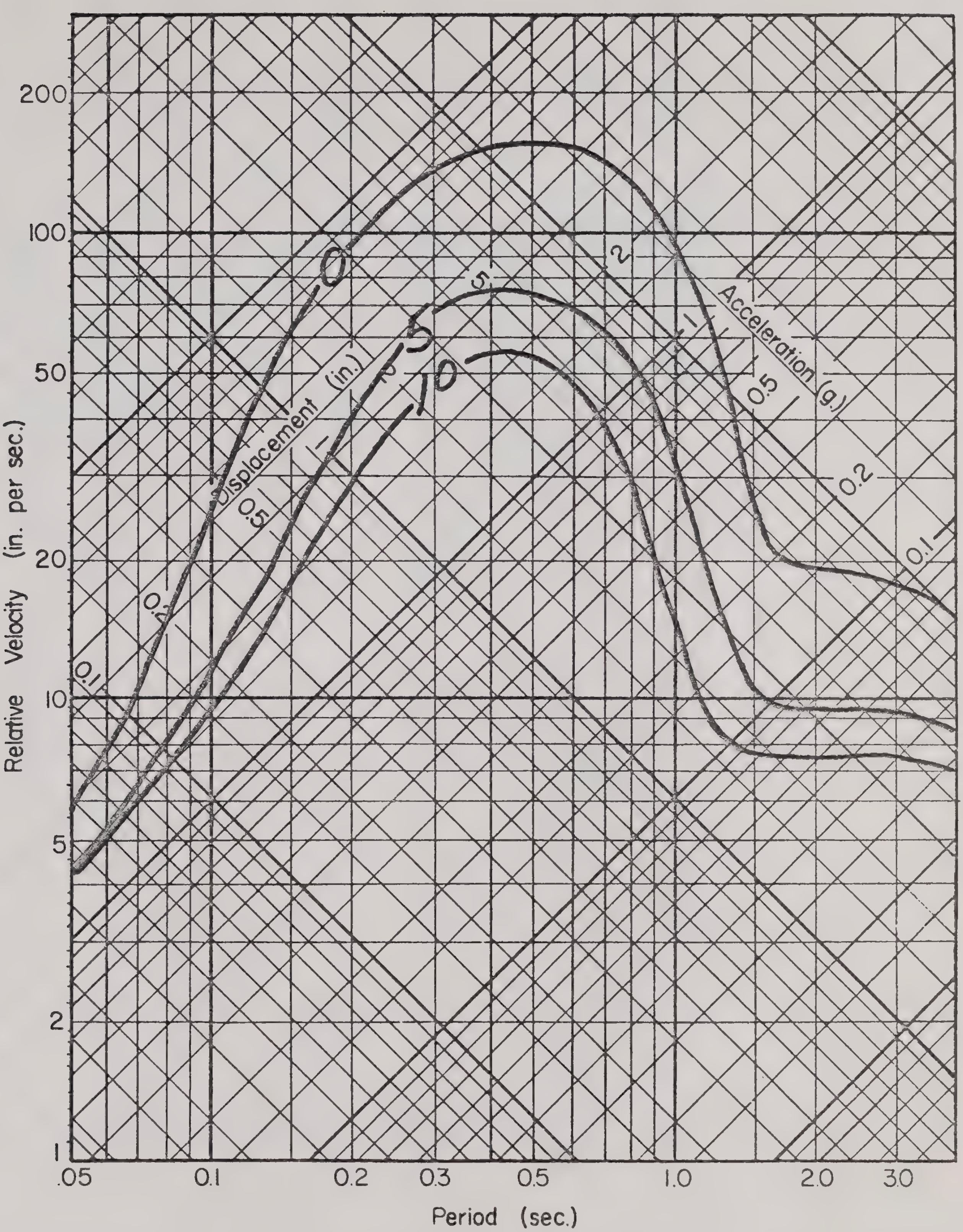


Figure 29. Response spectrum for Zone 1M of magnitude 7.0 event on Hayward fault for 0, 5, and 10% of critical damping.

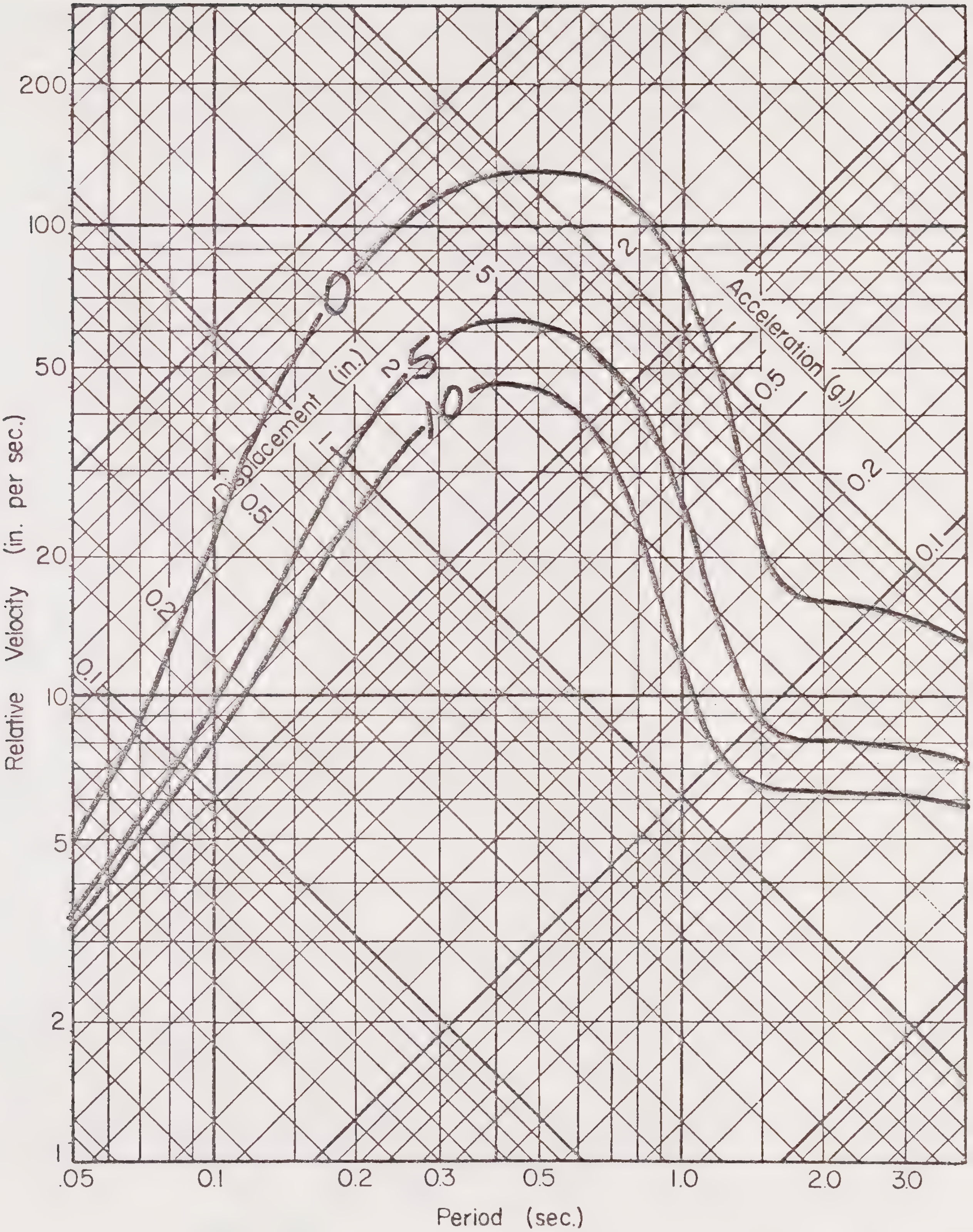


Figure 30. Response spectrum for Zone 2M of magnitude 7.0 event on Hayward fault for 0, 5, and 10% of critical damping.

Comparison of the response spectra for critical and semi-critical facilities with those for non-critical facilities shows that while the maximum ground accelerations are generally greater for the former, the spectral values are greater for the latter over a significant part of the range of periods. Therefore, the spectra for both use categories should be considered in the design of critical and semi-critical facilities.

IV. SECONDARY HAZARDS

A. LIQUEFACTION

Liquefaction involves a sudden loss in strength of a saturated cohesionless soil (predominantly fine grained sand) which is caused by shock or strain (such as an earthquake), and results in temporary transformation of the soil to a fluid mass. If the liquefying layer is near the surface, the effects are much like that of quicksand on any structure located on it. If the layer is in the subsurface, it may provide a sliding surface for the material above it. Liquefaction typically occurs in areas where the groundwater is less than 30 feet from the surface and where the soils are composed of poorly consolidated fine to medium sand. In addition to the necessary soil conditions, the ground acceleration and duration of the earthquake must also be of a sufficient level to bring on liquefaction.

A study of liquefaction potential in Southern San Francisco Bay by Youd, et al (1973) describes the potential for liquefaction in the Young Bay Mud as "...locally high where clear granular layers lie within Young Bay Sediments." For the purposes of this General Plan Element, we have assigned a high liquefaction potential to the areas of Alameda underlain by Bay Mud (Plate I) to serve as an admonition to developers that the probability of liquefaction is present, and must be addressed in pre-development investigations.

Youd, et al (1973) assigns a "Moderately Low" potential for liquefaction to the Merritt Sand, however, in the text of the paper they state that the area, in Alameda, underlain by Merritt

Sand "...has a continual potential for liquefaction" due to the high groundwater level. More recent reports on file with the City (particularly Woodward-Lundgren & Associates, May, 1974, and December, 1974) include subsurface data and laboratory test results which indicate that liquefaction could take place in the event of a severe earthquake. In both cases, mitigation measures were recommended. Based on this information we have also assigned a high liquefaction potential to the areas underlain by Merritt Sand (Plate I).

B. SETTLEMENT

Settlement may occur in unconsolidated soils during earthquake shaking as the result of a more efficient rearrangement of the individual soil particles. Settlements of sufficient magnitude to cause significant structural damage are normally associated with rapidly deposited sediments such as the Bay Mud or Merritt Sand or with improperly founded or poorly compacted fills.

The poorly consolidated sediments underlying Alameda can be expected to experience significant settlement during a strong to severe earthquake on either the San Andreas or Hayward faults. Estimates of settlement at a particular site must be made on an individual basis, but typical values, in areas of Merritt Sand, range up to about 5 inches, with more settlement likely in areas underlain by Bay mud deposits (reports on file with Building Department).

C. TSUNAMIS

Tsunamis are seismic sea waves generated primarily by vertical offsets of the sea floor accompanying submarine faulting. The

destructive power of tsunamis is due to the fact that they travel at velocities approaching 400 miles per hour. While they are generally imperceptible on the open sea, tsunamis have been recorded that crested to heights of more than 100 feet before slamming into shore. These great heights are rare, and depend on several factors such as offshore topography, tide phase, and coastline orientation and configuration.

Faulting at great distance is the most common source of tsunamis along the California coast. Typical source areas are the great submarine trenches off Chile and Alaska. The latter was the source area for the tsunami that struck Crescent City in 1964 with 13 foot waves claiming 11 lives, and causing over 11 million dollars damage. The Seismic Sea-Wave Warning System administered by the U.S. Coast and Geódetic Survey detects incoming tsunamis and supplies the endangered localities with the expected arrival times of the waves. The warning times vary with distance from the source, but for most tsunamis approaching the coast several hours are available to evacuate the citizens and to make emergency preparations.

Hazardous tsunamis which may occur along the coastline can only enter San Francisco Bay through the Golden Gate. This narrow constriction will severely limit the wave energy entering the Bay. The wave front will attenuate as it spreads into the Bay, and the probable affect at Alameda will be similar to rapidly fluctuating, exaggerated tidal cycles.

A tsunami inundation map prepared by Waterfront Design Associates (1975) using data from Weigle, 1970 and 1974, shows the areas

in Alameda which can be expected to experience flooding in the event of a tsunami with an expected recurrence interval of about 200 years. The affected portions of Alameda are delineated on Plate I (in pocket). The depth of flooding, wave heights, and damage potential cannot be determined from available information.

D. SEICHES

Seiches are standing waves produced in a body of water by winds, atmospheric changes, the passage of earthquake waves, etc. Studies of true seismic seiches are limited, but that by McGarr and Vorhis, 1968, of seiches induced by the Alaska earthquake of 1964 indicates that the largest recorded wave heights (double amplitude) did not exceed 1.2 feet. Since this is less than wave heights that would be expected from wind-induced waves, _true_ seismic seiches are not considered as constituting a significant hazard in open bodies of water in the study area. However, seiching in storage tanks may be important within the Alameda area.

E. LANDSLIDES

Earthquake induced landslides will not be a significant hazard within the study area due to low topographic relief and an absence of steep slopes. Artifically created slopes and natural slopes with gradients exceeding 50%, however, may experience localized slumping. These slopes are prevalent mainly along the estuary.

V. SAFETY CONSIDERATIONS

The City of Alameda is a mature, urban area that includes a balance of industrial, commercial and residential land uses. The City is located on an island that is linked to the nearby Oakland metropolitan area by two series of bridges and vehicular tubes that traverse the Alameda Harbor Tidal Channel to the north and the San Leandro Channel to the southeast. The City's location, away from major watershed areas, has minimized the City's exposure to major flood hazards. However, the Department of Housing and Urban Development (HUD) has delineated four general areas within the City that are "known to be subject to flooding." These areas include:

1. The Todd Shipyard area at the north end of Main Street.
2. The Webster Street area which includes (a) Webster Street at Atlantic Avenue and at Bethlehem Avenue, (b) the vicinity of Brush Street both easterly and westerly of Third Street, and (c) the north ends of Eighth Street, Nason Street and Ninth Street.
3. The Pacific Marina area.
4. The Golf Course and the older community of Bay Farm Island (Garden Road, Maitland Drive and Beach Road).

Flooding in most of these locations is relatively minor, and occurs due to temporary inadequacies in the local storm water pump systems. Flooding is most likely to occur when higher than average runoff coincides with a high tide. These conditions have a tendency to overload drain systems, causing water to back up into the streets and gutters of the particular area. Since flooding of this type is usually more inconveniencing than physically or economically hazardous, flooding is not a major problem in Alameda.

The City's insular location made it attractive as a center of maritime industry, and soon the primary industrial focus became the shipyards and docks edging the island. However, unlike other industrial areas, the City retained a substantial residential-commercial base. The varied nature of Alameda's urban landscape has played an important role in shaping the issues and concerns of the City, including those that relate to the level of urban fire hazard.

VI. EXISTING FIRE PROBLEMS

A. MAJOR FIRE PROBLEMS

Potential fire outbreaks in large apartment complexes such as those in the South Shore Beach and Shorepoint Road areas, comprise the City's major fire problem (personal communication Ernest F. Servente, Fire Chief). The difficulties encountered in delivering personnel and water to such large, and often spread-out structures, form the basis of this specialized fire concern.

Other fire problems of a less critical nature are potential ship fires and industrial fire outbreaks in the dock areas near the Encinal terminals and the Todd Shipyards. Since ship fires involve problems and strategies that depend on the design of the individual ship, the large variety of craft utilizing the terminals compounds the fire hazard and hinders efficient fire suppression.

B. CRITICAL FACILITIES

The City of Alameda contains approximately 49 structures whose presence and continued functioning constitutes a vital role in a potential emergency, or whose failure might prove catastrophic. Among these facilities are four fire stations, the Police Station, City Hall, one hospital, 16 auditoriums, 21 schools and five other facilities, since each facility represents an important element in the emergency response strategy of the City, they have been given added fire-protection considerations.

Table 8 lists the types of critical facilities to be found in the City, and describes their location and maximum building height. Plate II shows the location of each structure within the City.

TABLE 8

LIST OF CRITICAL BUILDINGS
CITY OF ALAMEDA

Theaters	Location	Max. Building Height
Alameda	Central and Oak	3 stories
Showcase	2200 Block of Shoreline	2 stories
Hospitals		
Alameda	Clinton and Willow	6 stories
Fire Stations		
	Park and Encinal	2 stories
	Pacific and Grand	1 1/2 stories
	Pacific and Webster	1 1/2 stories
	Island Drive	4 stories
Police Stations		
City Hall	Santa Clara and Oak	3 1/2 stories
Ambulance Service		
	Lincoln and Oak	2 stories
Libraries		
Main	Santa Clara and Oak	2 1/2 stories
Branch	Santa Clara and 8th	1 story
Red Cross		
	1800 Block of Central	2 1/2 stories
Schools		
Encinal High School	210 Central	2 stories
Woodstock	Atlantic and 3rd	1 story
Chipman	Pacific and Marshal Way	2 stories
Longfellow	Pacific and 5th	2 stories
Paden	400 block of Central	2 stories

TABLE 8

LIST OF CRITICAL BUILDINGS
CITY OF ALAMEDA
(con't)

Schools	Location	Max. Building Height
St. Barnabas	Central and 6th	2 stories
Washington	Santa Clara and 8th	2 stories
Mastick	Santa Clara and Bay	1 story
Franklin	San Antonio and Paru	2 stories
Wood	400 Block of Grand	3 stories
Lum	Otis and Grand	1 1/2 stories
St. Josephs	Chestnut and San Jose	2 1/2 stories
Haight	Santa Clara and Chestnut	2 stories
Alameda High	Encinal and Walnut	3 stories
Christian	2200 Block of Pacific	1 story
Island High	Eagle and Everett	1 story
Edison	Buena Vista and Pearl	1 story
Otis	High and Fillmore	2 stories
St. Phillip Neri	High and Jackson	2 stories
Lincoln	Central and Mound	3 stories
College of Alameda	Webster and Atlantic	3 stories
Auditoriums		
Masonic Temple	Park Street and Alameda	3 stories
Eagles Hall	Oak Street and Alameda	2 stories
Elks Club	2200 Block of Santa Clara	3 stories
Veterans Bldg.	Walnut and Central	2 1/2 stories
Alameda High School	Encinal and Walnut	3 stories
Encinal High School	210 Central Avenue	2 stories
Washington School	Santa Clara and 8th	2 stories
Wood School	400 Block of Grand St.	3 stories
Chipman School	Pacific and Marshal Way	2 stories
Lincoln School	Central and Mound	3 stories
Longfellow School	Pacific and 5th	2 stories

TABLE 8

LIST OF CRITICAL BUILDINGS
CITY OF ALAMEDA
(con't)

Auditoriums	Location	Max. Building Height
Haight School	Santa Clara and Chestnut	2 stories
St. Josephs	Chestnut and Antonio	2 1/2 stories
St. Barnabas	Central and 6th	2 stories
Lum School	Otis and Grand	1 1/2 stories
College of Alameda	Atlantic and Webster	3 stories

C. FACTORS DETERMINING OVERALL FIRE HAZARD

Four major factors contribute to the level of fire hazard in an urban area. They are: (1) limited access, (2) inadequate water supplies, (3) hazardous land uses, and (4) response time intervals.

1. Limited Access

Limited access, as used herein, refers to the difficulty encountered in delivering adequate equipment and personnel to a fire. Access to an area or a particular structure is affected by street widths and layouts, building design, and land use patterns. The fire problems associated with the apartment complexes in the City are examples of access-related issues and concerns.

2. Inadequate Water Supply

Inadequate water systems result from insufficient volumes of deliverable water or inadequate pressure in the system of a given area. Water-related fire fighting problems can effectively hinder the suppression capabilities in a given area, and increase the likelihood of a spreading, multi-structure fire.

3. Hazardous Land Uses

Land uses such as industrial plants dispensing or utilizing flammable materials, tend to increase the overall fire hazard. Although fire regulations to deal with these specialized fire situations are stipulated in local codes and ordinances, extra caution is necessary in adjacent land use decisions.

4. Response Time Intervals

"Response time" is the time required for a fire fighting unit to respond to a fire in a specified area. The time required for such a response is a critical element in the overall fire fighting strategy. Response times are determined by traffic flow patterns, and more importantly, by the placement of fire stations in a community. A strategic placement of stations can optimize the coverage in an area, and help provide adequate levels of protection throughout a community.

A response time of at most six minutes is considered absolutely essential for the welfare of a community. The City of Alameda, through its placement of fire stations, has improved upon this base level of protection. Almost all of the City is less than two minutes away from a fire station with the only area significantly outside the two-minutes response envelope being the Naval Air Station which has its own fire-fighting capability.

D. GAS AND ELECTRICAL UTILITY LINES

Plate II shows the location of the major gas and electrical utility lines that service the City. Their presence, in and of themselves, constitutes only a minimal fire hazard. However, in an earthquake situation, ruptured gas mains and downed power lines could significantly contribute to the likelihood of local fire. The Pacific Gas and Electric Company maintains shut-off points along each route, and following an earthquake or other disaster of a similar nature, escaping gas or downed electrical lines should be shut-off.

VII. EXISTING PROTECTION

The City of Alameda falls entirely within the area of responsibility of the Alameda City Fire Department, Chief Ernest F. Servente. The Fire Department operates from four stations located at the following addresses:

Park and Encinal
Pacific and Grand
Pacific and Webster
Island Drive
(See Plate II for location)

The location of these four stations allows the Department to respond to an emergency in the City within a two minute period.

The City Fire Department is staffed by 102 professional fire-fighting personnel and is organized in the following manner:

1 Chief
5 Assistant Chiefs
11 Captains
12 Lieutenants
24 Apparatus Operators
49 Firemen

The Alameda City Fire Department has an equipment inventory comprising 9 pieces described as follows:

6 1250 gallon per minute pumpers
2 Trucks
1 1000 gallon per minute fireboat

The Fire Department responds annually to approximately 1800 alarms, 50% of which are structural fires. The remaining alarms involve automobile fires, first aid calls, miscellaneous fires and false alarms.

The Alameda City Fire Department has attained a Class 3 fire protection rating from the Insurance Services Office (ISO), a national organization that periodically evaluates fire departments throughout the nation on a Class 1-10 basis. Using their criteria, a Class 1 department provides the most ideal level of protection, and is only rarely assigned. A Class 3 ranking, such as that awarded the City's Department, has been granted to about 25% of the larger metropolitan fire departments in the nation. Class 2 rankings have been given to only about the upper 3% of cities with populations over 25,000.*

The Alameda City Fire Department has entered into a mutual aid agreement with all of the cities in the County of Alameda. In the event of a large scale fire in the City, the Fire Department could enlist almost unlimited assistance in the form of personnel and equipment from fire departments throughout the County.

* International City Managers Assoc., 1968, Municipal Fire Administration.

VIII. CONCLUSIONS

A. SEISMIC AND GEOLOGIC HAZARDS

1. The City of Alameda is located in a part of California considered seismically active.

2. The states of activity of the major faults affecting the City have been evaluated using available published and unpublished data. Major conclusions are:

   a. The San Andreas fault is active and is expected to be the source of a magnitude 8.0-8.5 earthquake in the next 50-100 years.

   b. The Hayward fault zone is active and is expected to be the source of future significant earthquakes.

   c. Earthquakes can and will occur on other faults in the region but their effects on the study area will be less than those for the events on either the San Andreas or Hayward fault zones.

3. The earthquakes expected from the San Andreas and Hayward fault zones will result in ground shaking of approximately equal intensity in Alameda, depending on the characteristics of earthquake shaking applicable to a particular structure. Since the earthquake from the San Andreas fault zone has a greater risk of occurrence than that from the Hayward fault zone, the former is considered applicable to structures of non-critical use, and both events should be considered in the design of critical facilities.

4. Microzonation of the study area is based on the distance from the Hayward and San Andreas fault zones and the type of earth materials present. The ground shaking characteristics of each zone for each expected earthquake are presented as response spectra in the report, and the generalized characteristics of expected shaking to be applied to each of the zones in the City are summarized in Table 7. The areal distribution of the zones is shown on Plate 1. The response spectra and Table 7 provide the necessary information to enable a structural engineer to modify the existing building codes.

5. Liquefaction and settlement are considered significant hazards in all of the City. Soils engineering reports prepared for sites in the City should specifically address the problems of liquefaction and settlement, and evaluate them using the ground shaking parameters presented in this report.

6. Landsliding is not a significant hazard in the City because of the lack of significant topographic relief.

7. The hazard from tsunami (i.e. "tidal waves") is significant in the low-lying areas of the City. The area expected to be inundated by a tsunami with a recurrence interval of approximately 200 years is shown on Plate I.

B. FIRE HAZARDS

1. Fire hazards in the City of Alameda are of a wholly urban nature.

2. The major problem is fire in the large apartment complexes such as those in the South Shore Beach and Shore Point Road areas.

3. Problems of a somewhat less critical nature include fires at the Todd Shipyards and the Encinal terminals.

4. Rupture of local gas lines or downed electrical utility lines could compound fire hazards in the event of a major disaster such as an earthquake.

5. The City of Alameda receives adequate fire protection through the City Fire Department

C. FLOOD HAZARDS

1. Because of its geographical position, the City of Alameda does not have a flood hazard other than that from tsunami noted above.

ACKNOWLEDGEMENTS

CITY COUNCIL

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George W. Beckam, Jr., Vice Mayor
Lloyd E. Hurwitz
Anne B. Diament
Richard J. Sherratt
John D. Goss, City Manager

PLANNING BOARD

Don Perata, Chairman
Joan Narahara, Vice Chairman
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Philip H. Long
Michael Gorman
Don E. Patterson, Planning Director

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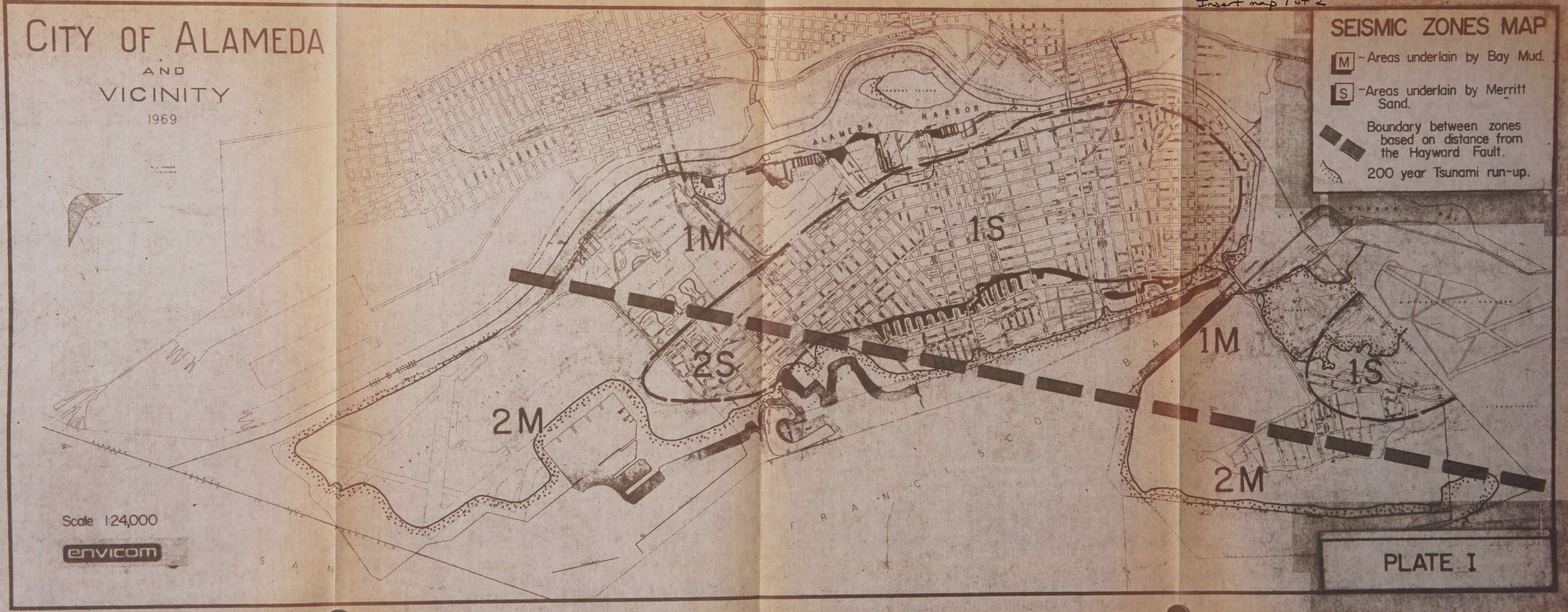
CITY OF ALAMEDA
AND
VICINITY
1969
PLATE II
FACILITIES AND
FIRE RESPONSE
EXPLANATION
Emergency Response Facilities
H - Hospital
F - Fire Station
P - Police Station
AM - Ambulance Service
Non-Emergency Response Facilities
S - School
T - Theatre
A - Auditorium
L - Library
RC - Red Cross
PA - Public Assembly Facilities (100 or more)
Utility Lines
Electric Lines
Gas Lines
Water Lines
Telephone Lines
Sewer Line (maintained by EBMUD)
Sewer Line (maintained by City of Alameda)
Sub Stations
Electrical
Sewage (EBMUD)
Sewage (City of Alameda)
Major access route.
Approximate limit of area with 2-minute response time at 30-35 MPH under normal conditions.
Scale 1:24,000
envicom
ALAMEDA
HARBOR
GOVERNMENT ISLAND
SAN FRANCISCO BAY
SAN LEANDRO BAY
CHANNEL

86 00559
Insert map 1 of 2



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